5. Water Resources Assessment for the Planning Region

This section provides a description of the quantity and quality of water resources found within the Jemez y Sangre Water Planning Region. The information presented is drawn primarily from a detailed water supply study of the Jemez y Sangre planning region (Duke, 2001), which was conducted on behalf of the JySWPC. This section summarizes the more pertinent results of the 2001 water supply study and presents a concise assessment of water resources within the planning region. Most of the figures and tables presented in this section are derived directly from the Duke study (2001).

The major portion of the Jemez y Sangre Water Planning Region lies within the Española Geologic Basin, with a small part of the region extending into the northernmost portion of the Albuquerque Basin. As shown in Figure 1 (Section 1), the region has been divided into ten watersheds, or sub-basins: Velarde, Santa Cruz, Santa Clara, Los Alamos, Pojoaque-Nambe, Tesuque, Caja del Rio, Santa Fe River, North Galisteo Creek, and South Galisteo Creek.

The following subsections:

- Summarize the climate, surface water and groundwater supply, and water quality within the Jemez y Sangre Water Planning Region.

- Summarize water supply and quality within the planning region and each of the ten sub-basins.

- Summarize the water supply considering the legal constraints presented in Section 4.

Water budgets for each sub-basin, which include detailed data about inflow, outflow, and use, are presented in Section 6.

5.1 Weather and Climate

Precipitation (rainfall and snowfall) and evaporation are the primary controls on the entry and exit of water in the planning region. These are also important contributing processes to surface runoff and groundwater recharge. The Duke water supply study compiled data from 12 weather stations located within the planning region and maintained by the National Climatic Data Center, a branch of the National Oceanic and Atmospheric Administration (NOAA). Statistical analyses of temperature, precipitation, and snowpack were used to produce a general description of the region's climate.

5.1.1 Temperature

Table 6 lists the mean temperatures and the mean of annual maximum and minimum temperatures at each of the 12 weather stations. January is typically the coldest month of the year and July the warmest. At the Santa Fe weather station, near the center of the planning region, the average January maximum temperature is 42° F and the average minimum is 17° F. At the same station, the average July maximum temperature is 84° F and the minimum is 56° F.

Table 6. Mean Annual Temperature and Mean Annual Extreme Temperatures

Station Number	Station Name	Mean Temperature (°F)		
		Annual	Annual Maximum	Annual Minimum
290041	Abiquiu Dam	50.0	64.3	35.6
290245	Alcalde	51.3	68.1	34.5
290743	Bandelier National Monument	50.1	68.0	32.2
291982	Cochiti Dam	54.3	68.6	39.9
292820	El Rito	48.5	63.2	33.8
293031	Española	51.7	68.8	34.6
294369	Jemez Springs	52.0	66.8	37.1
295084	Los Alamos	47.9	59.8	36.0
296676	Pecos Ranger Station	48.9	65.0	32.7
298072	Santa Fe	49.0	62.9	35.1
298085	Santa Fe 2	50.5	64.1	36.9
298518	Stanley 1 NNE	49.3	65.5	33.0

Source: Duke, 2001 (Table 2-4)

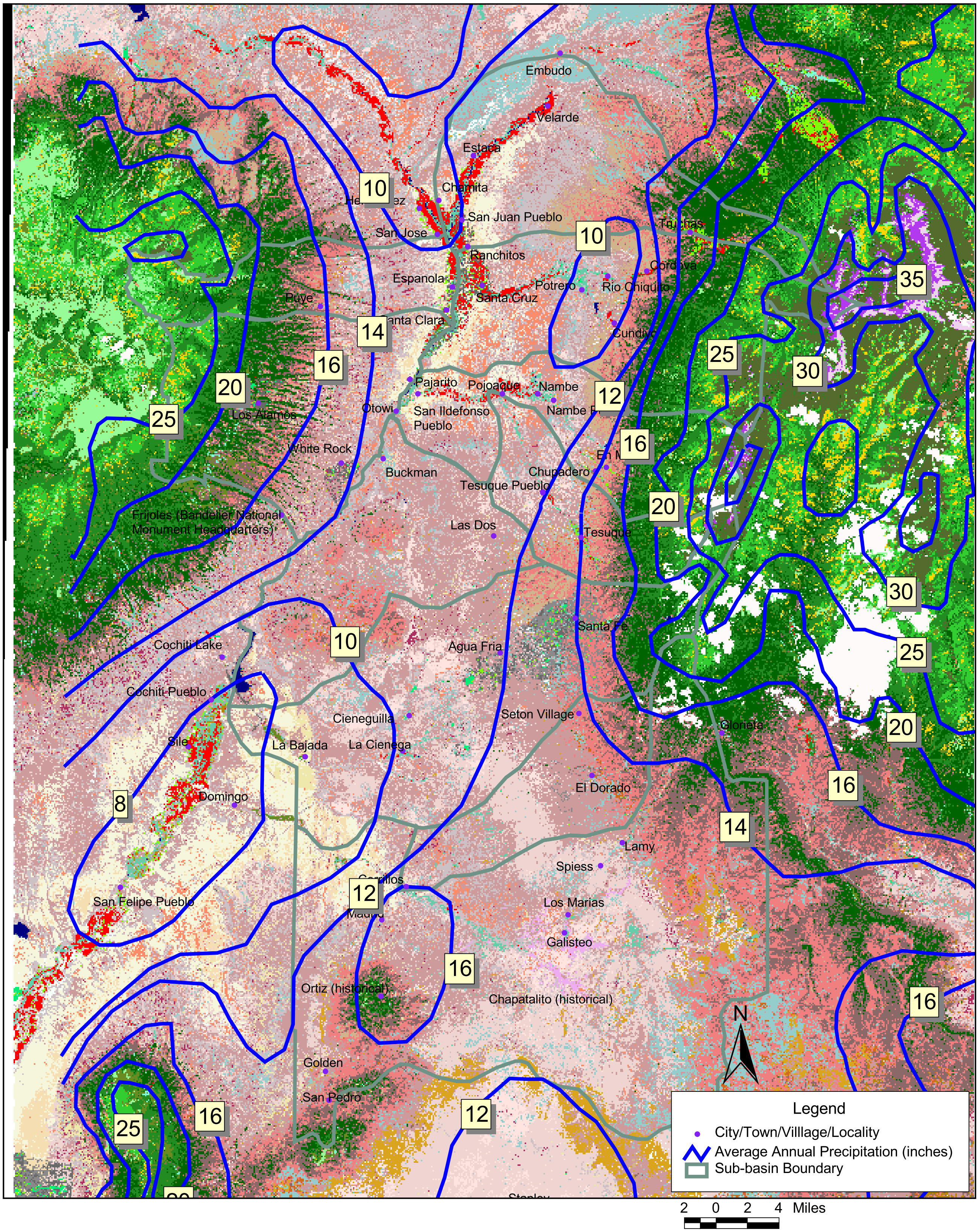
Mean annual temperatures vary throughout the planning region, generally decreasing as elevation increases. At Cochiti Lake near the southern part of the region (elevation 5,010 ft msl), the mean annual temperature is 54.3°F; El Rito near the northern extent of the region (6,870 ft msl) has a mean annual temperature of 48.5°F.

5.1.2 Precipitation

Figure 7 is a contour plot showing the distribution of average annual precipitation in the Jemez y Sangre planning region based on precipitation maps previously prepared by the SCS (1972) and Wasiolek (1995). This figure illustrates a large spatial variation in average annual precipitation over the planning region. Average annual precipitation in the mountain ranges on either side of the study area approaches 30 to 35 inches, whereas mean annual precipitation in the lowest elevations is about 8 inches. Table 7 lists mean annual average precipitation (combined rain and snow), along with the annual minimums and maximums for the recorded histories at 12 weather stations.

Monthly variation in precipitation was determined by calculating the average monthly precipitation over the 30-year period (1961 to 1990), and comparing it to monthly totals (Duke, 2001). A prominent peak in mean monthly precipitation usually occurs in August as a result of moisture that moves into the area from the Gulf of Mexico at this time of year (Tuan et al., 1969). The cumulative mean precipitation in the summer months of June, July, and August contributes more than 40 percent of the total annual precipitation.

As suggested by the statistical indicators in Table 7, annual precipitation is extremely variable within the planning region. For example, in the Santa Fe area (Santa Fe and Santa Fe 2 stations), the annual precipitation appears to fluctuate over a range of about 50 percent above and below the long-term average. Statistical analyses of historical data suggest that extended wet and dry periods tend to alternate with each other in cycles, with each cycle approximately 10 to 15 years in length (Duke, 2001). Figure 8 presents plots of the annual Palmer Drought Severity Index (PDSI) for the southern end of the planning region. PDSI values approaching –4 represent extreme drought conditions, while values approaching +4 represent extremely wet



Source: Duke, 2001 (Figure 5-23)

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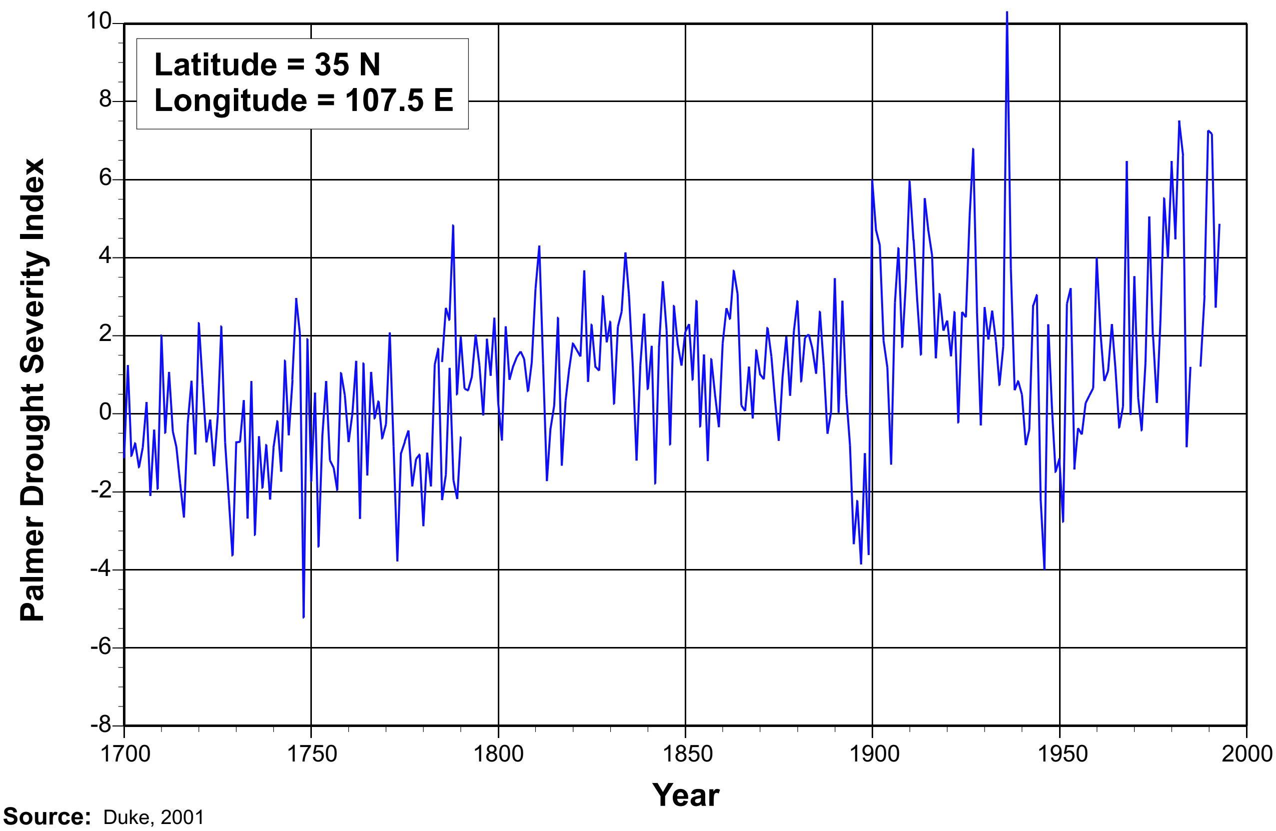
JEMEZ Y SANGRE REGIONAL WATER PLAN

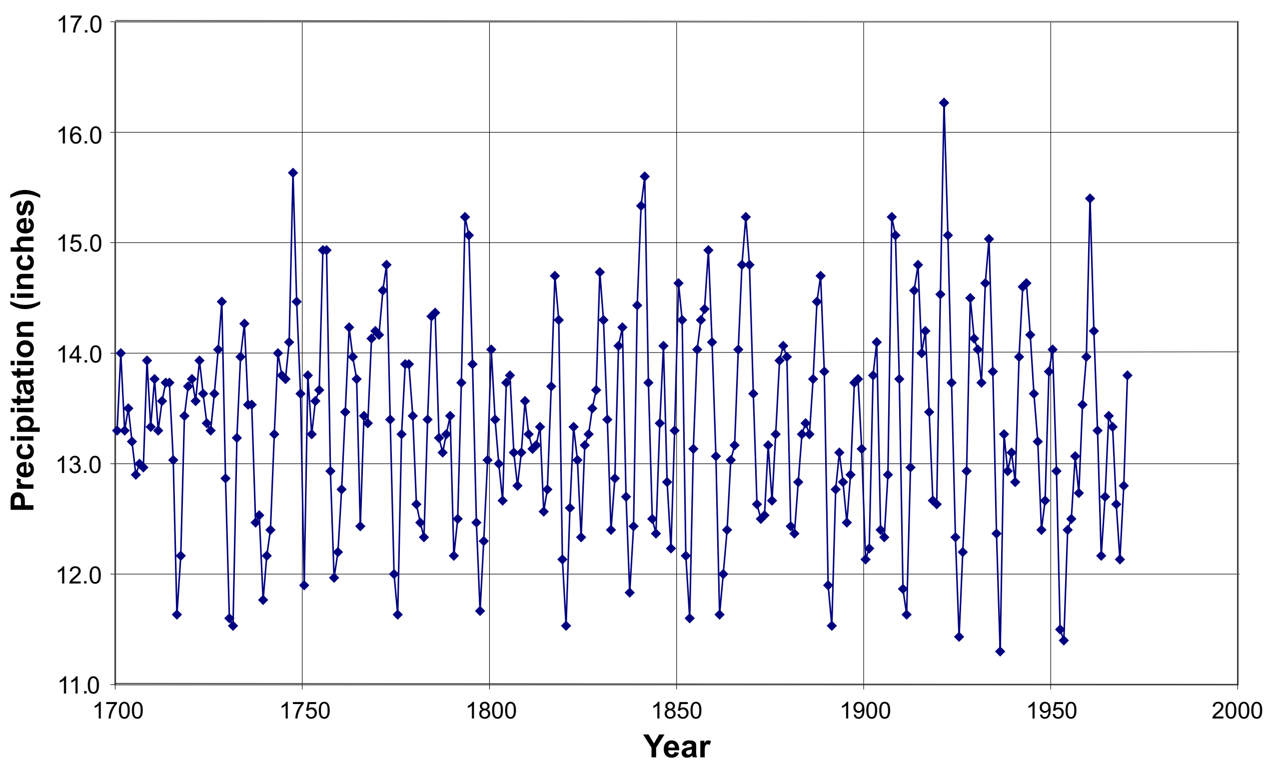
Average Annual Precipitation for the Planning Region

Figure 7



Source: Duke, 2001

Note: Paleoclimate Station 51
North-Central New Mexico



Note: Reconstructed precipitation data is a 3-year average

JEMEZ Y SANGRE REGIONAL WATER PLAN

Annual Palmer Drought Severity Index and Reconstructed Precipitation Data (from Tree Rings) at Arroyo Hondo

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Figure 8

conditions. Also shown in Figure 8 is the reconstructed precipitation at Arroyo Hondo based on tree ring data, illustrating several droughts including a drought in the 1950s. The variability in precipitation is an important factor in long-term planning, especially considering that the past 25 years has been perhaps the wettest period of the last 300 years.

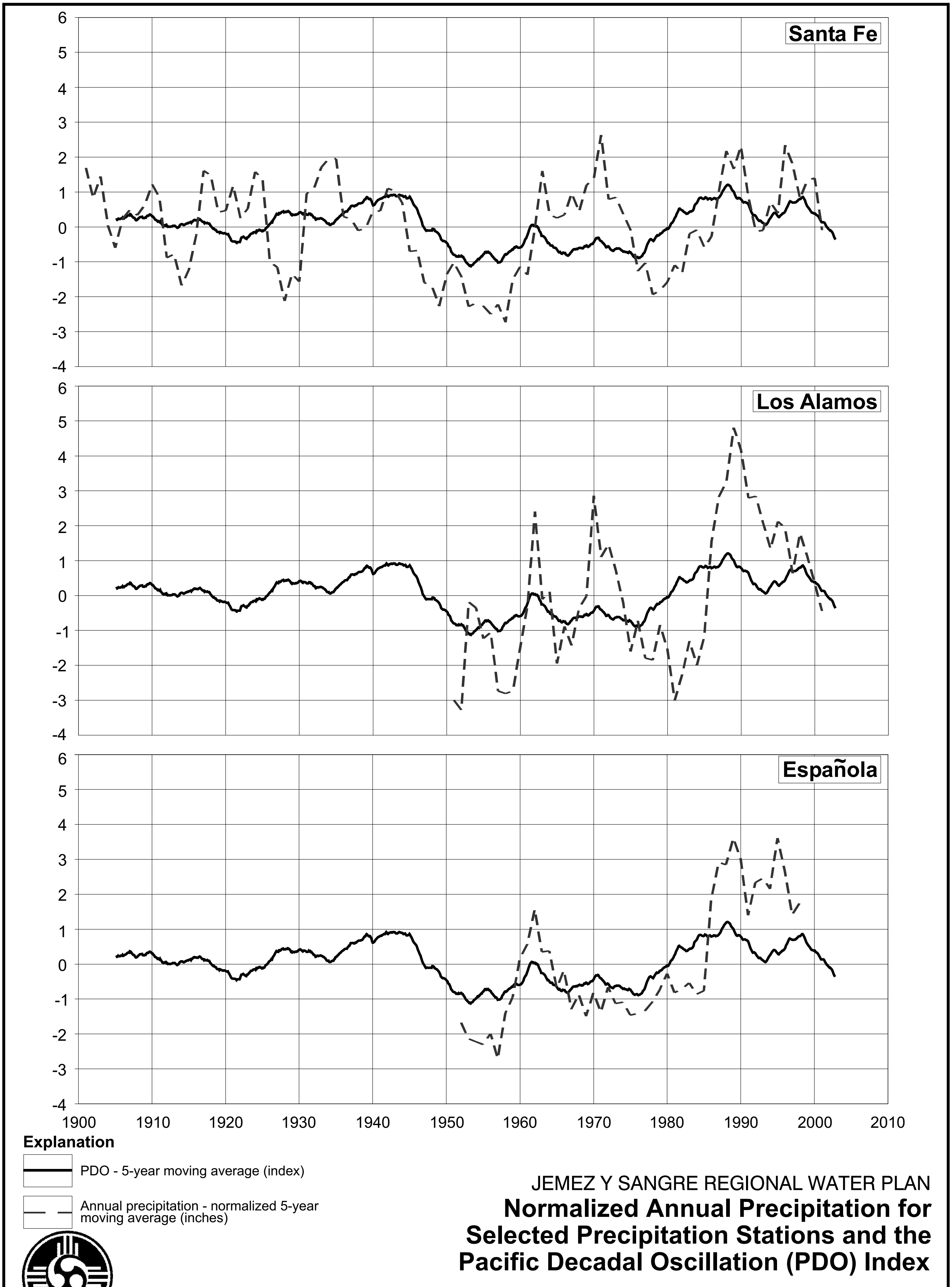
Table 7. Statistical Summary of Annual Precipitation at Selected Weather Stations

Station Number	Name	Years [a]	Annual Precipitation (inches)				
			Mean	Median	Standard Deviation	Maximum	Minimum
290041	Abiquiu Dam	1957-1963	9.95	9.77	1.94	14.38	4.98
290245	Alcalde	1953-1996	9.89	9.28	3.05	16.16	2.66
290743	Bandelier National Monument	1931-1976	15.50	14.85	4.17	25.96	4.94
291982	Cochiti Dam	1975-1996	12.59	12.05	3.49	19.86	6.82
292820	El Rito	1931-1996	12.08	12.04	2.84	21.90	4.95
293031	Española	1938-1996	9.98	9.81	2.65	20.30	3.76
294369	Jemez Springs	1931-1996	17.44	16.54	4.39	28.72	6.17
295084	Los Alamos	1931-1996	18.40	18.34	4.46	30.34	6.80
296676	Pecos Ranger Station	1931-1996	16.17	16.46	3.67	25.34	9.23
298072 298085	Santa Fe Santa Fe 2	1868-1996	13.84	13.37	3.39	21.75	5.03
298085	Santa Fe 2	1972-1996	14.27	13.77	3.03	20.09	7.89
298518	Stanley 1 NNE	1954-1996	12.27	12.17	3.65	21.28	4.65

[a] Years of record used to determine statistical descriptors of annual precipitation.

Source: Duke, 2001 (Table 2-2)

The Pacific Decadal Oscillation (PDO) also has a strong influence on the weather patterns in New Mexico (Liles, 2000). The PDO is a long-term temperature fluctuation (20 to 30 years) of the Pacific Ocean, when temperatures in the western Pacific Ocean are warmer than average and temperatures in the eastern Pacific Ocean are cooler than average. Several independent studies find evidence for just two full PDO cycles in the past century: "cool" PDO regimes prevailed from 1890 through 1924 and again from 1947 through 1976, while "warm" PDO regimes dominated from 1925 through 1946 and from 1977 through (at least) the mid-1990s. Figure 9 illustrates the correlation between PDO and precipitation in the Jemez y Sangre region.



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JEMEZ Y SANGRE REGIONAL WATER PLAN

Normalized Annual Precipitation for Selected Precipitation Stations and the Pacific Decadal Oscillation (PDO) Index

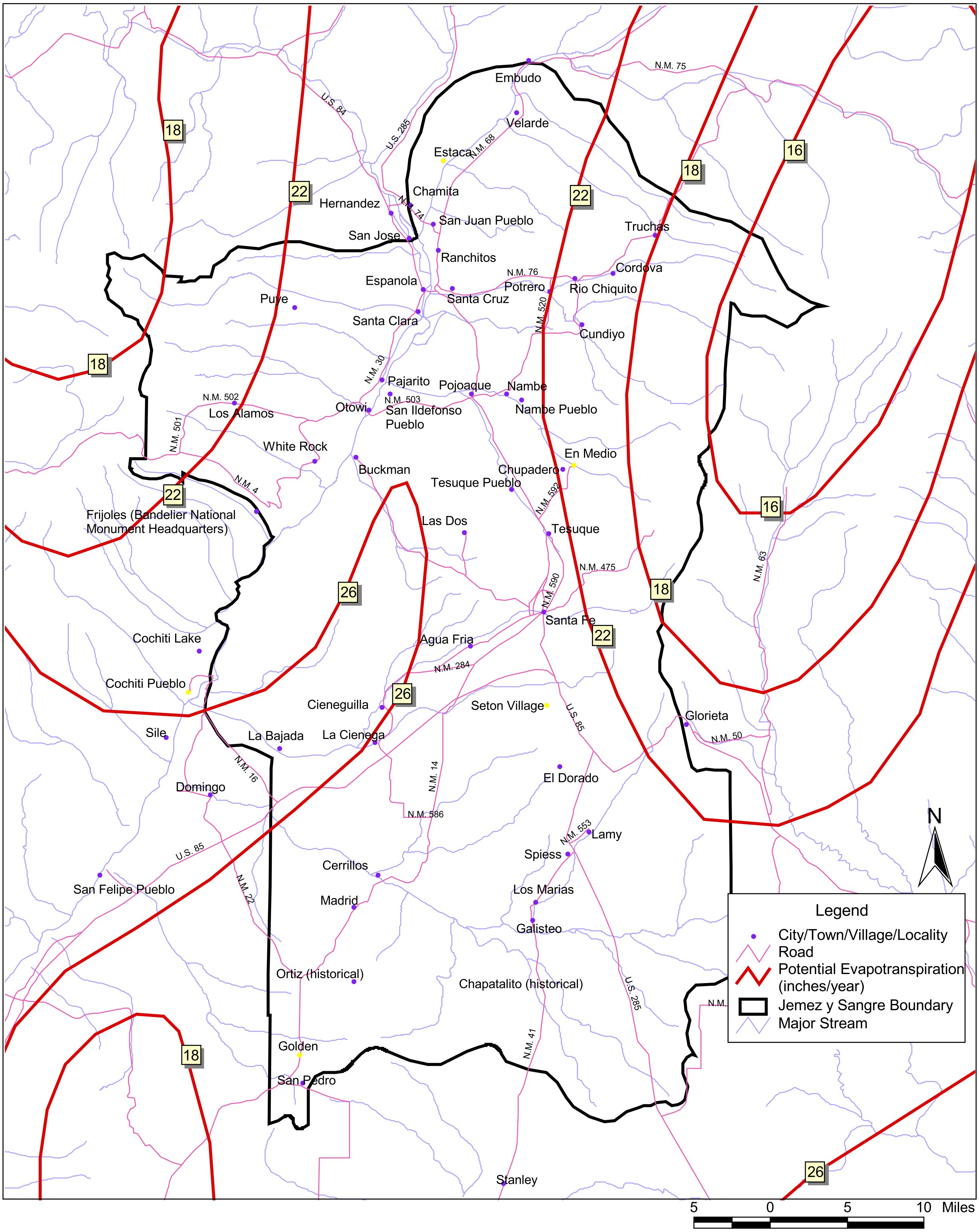
Figure 9

As shown in Figure 9, when the PDO is warm (positive) there is a strong trend of above-average precipitation in the region, and when the PDO is cool (negative), there tends to be below-average precipitation. During a negative or “cool” phase of the PDO, precipitation is about 91 percent of average in the Jemez y Sangre region. Streamflows during the negative periods are typically about 73 percent of the average streamflow. The positive PDO cycles tend to be wetter, averaging 110 percent of normal precipitation and 114 percent of average run-off (Liles, 2000).

5.1.3 Evaporation and Evapotranspiration

Both free water surface (FWS) evaporation and potential evapotranspiration (PET) rates were determined and presented in the Duke water supply study (2001). The FWS evaporation rate is meant to represent the rate of evaporation from an extensive free water surface, such as a lake. The potential evapotranspiration rate is intended to represent the amount of evaporation and evapotranspiration that would occur from areas of soil or vegetation if they were wet all the time. FWS rates were taken from an NOAA Technical Report (Farnsworth and Thompson, 1982) that discusses the distribution of evaporation rates over the entire state (Duke, 2001). PET rates were determined using a map of PET quantities prepared by Tuan et al. (1969) (Figure 10). Table 8 shows the estimated evapotranspiration rates for each of the sub-basins in the Jemez y Sangre region.

As shown in Duke (2001) and in Figure 10, both annual FWS evaporation and annual PET exceed precipitation throughout the study area, except at the highest elevations. Although the annual evaporation or evapotranspiration may exceed annual precipitation, precipitation for a given storm event may exceed the evaporation or evapotranspiration during the same time period, thus resulting in recharge. Evapotranspiration is used in Section 6 to calculate water budgets for each of the ten sub-basins within the planning region.



Source: Duke, 2001 (Figure 2-8)

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JEMEZ Y SANGRE REGIONAL WATER PLAN

Average Potential Evapotranspiration Rate

Figure 10

Table 8. Estimated Evaporation and Evapotranspiration Associated with Surface Water, by Sub-Basin

Sub-Basin	Free Water Surface			Riparian Areas			Total ET Volume [c] (afy)
	Estimated Area [a] (acres)	Evaporation		Estimated Area [b] (acres)	PET Rate Average (in/yr)	ET Volume Riparian (afy)	
		Rate (in/yr)	Volume (afy)				
Velarde (including the Rio Grande)	195 [d]	45	731	1,000	22.1	1,842	2,580
Santa Cruz	132	45	495	2,000	19.1	3,183	3,680
Santa Clara	None	45	0	310	21.2	550	550
Los Alamos	106	45	398	1,027	18.6	1,592	1,990
Pojoaque-Nambe	120	45	450	1,365	21.1	2,400	2,850
Tesuque	80	45	300	540	21.8	980	1,280
Caja del Rio	None	45	0	92	26.0	200	200
Santa Fe River	80	45	300	440	24.0	880	1,180
North Galisteo Creek	None	45	0	65	24.0	130	130
South Galisteo Creek	125	45	469	1,050	24.0	2100	2,570

Source: Duke, 2001 (Table 3-11)
[a] FWS area estimated using 1992 Landsat image.
[b] Riparian area estimated using 1992 Landsat image.
[c] Total ET volume = FWS evaporation volume + riparian ET volume
[d] Rio Grande surface

in/yr = inches per year
afy = acre-feet per year
PET = Potential evapotranspiration
ET = Evapotranspiration
FWS = Free water surface

5.2 Surface Water Supply

Figure 3 (Section 3) shows the major watercourses and drainage patterns found in each of the sub-basins. Two of the sub-basins, Santa Clara and Los Alamos, originate on the east slope of the Jemez Mountains and drain eastward to the Rio Grande, while the remaining eight drain the west slope of the Sangre de Cristo Range on the east side of the Rio Grande. As delineated for this plan, the boundaries of the sub-basins are not everywhere coincident with actual drainage boundaries but may be aligned with county boundaries. Excluding areas omitted by these “artificial” boundaries, the total study area drainage encompasses 1,892 square miles.

Sub-basin attributes examined include drainage area, mean land elevation, land surface relief, main channel slope, mean annual precipitation, and mean annual PET. Table 4 (Section 3) lists some of the pertinent physical attributes of each of the sub-basins. Figure 2 (Section 3) is a composite digital elevation model (DEM) map for the entire planning region, which was built by combining numerous 15-minute maps.

5.2.1 Regional Surface Water Flow System

The major perennial waterway in the region is the Rio Grande. The average annual flow entering the planning region from the Rio Grande is nearly 600,000 afy. The average increase in river flow between the Embudo and near Otowi Bridge Gages appears to be greater than 400,000 afy. Most of this is attributable to inflow from the Rio Chama, which includes imported SJC Project water, with much lesser amounts contributed by surface outflows from sub-basins and groundwater discharge to the Rio Grande. The mean annual flow of the Rio Grande at the Near Otowi Bridge Gage is close to 1.1 million afy. This is probably close to the average amount of water that flows into Cochiti Lake because river gains and losses on the reach between Otowi and Cochiti Lake are probably minor in comparison to total flow in the river. As discussed in Section 4, use of this supply is limited by the provisions of the Rio Grande Compact.

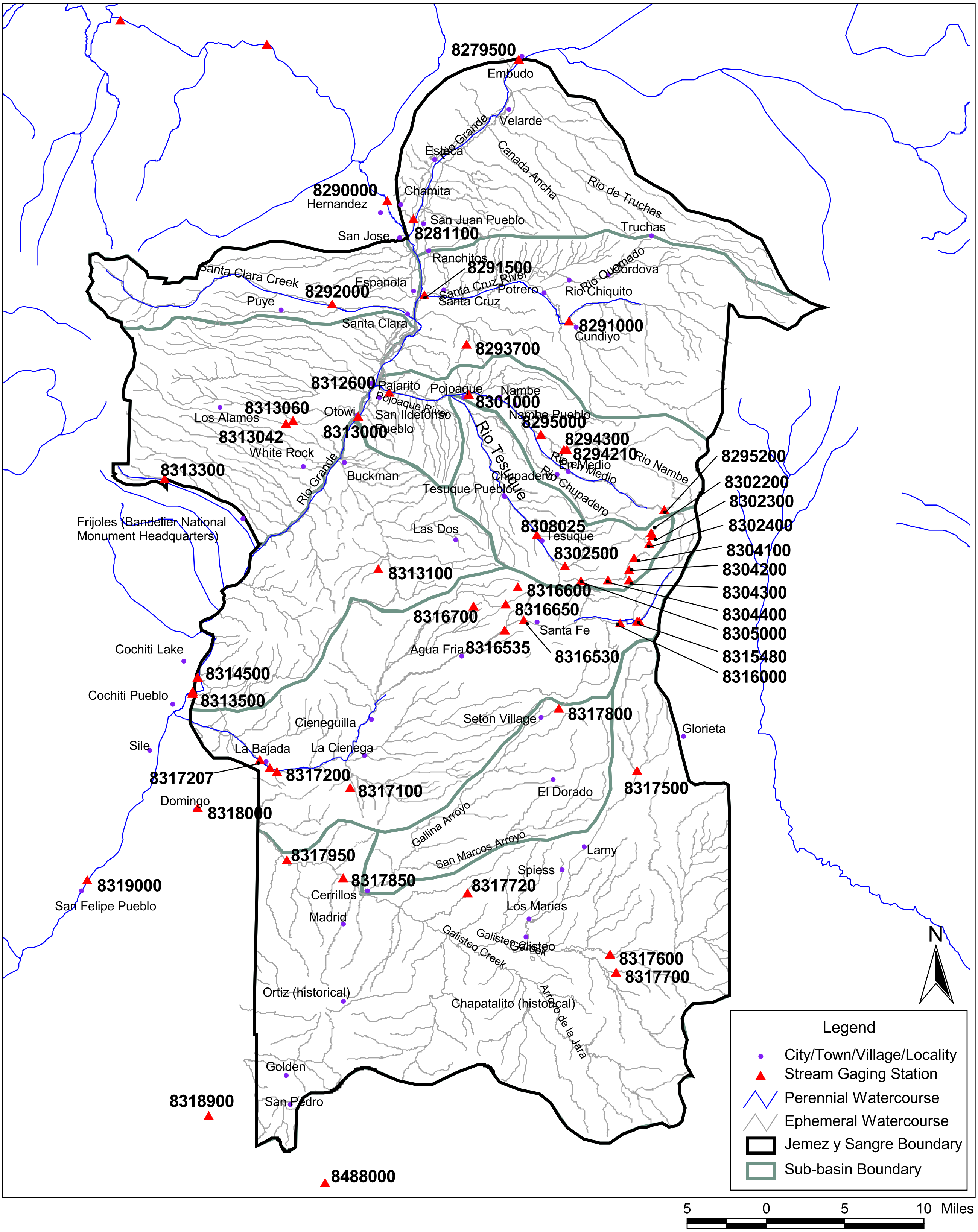
5.2.2 Streams and Rivers

Perennial and ephemeral streams in the planning region were identified using a combination of a USGS 1:500,000 surface-drainage map and, where available, daily streamflow records. These streams are shown on Figure 3. The two dominant waterways flowing into the region are the Rio Grande and the Rio Chama. Other prominent regional perennial streams that contribute directly or indirectly to the Rio Grande include the Santa Cruz River, Santa Clara Creek, Rio en Medio, Pojoaque Creek, Rio Tesuque, Pojoaque River, and the Santa Fe River.

The Duke water supply study (2001) identified 61 USGS stream gaging stations that were either within the planning region or monitored flows indicative of surface water processes occurring in the region. Figure 11 shows the locations of the sites and Table 9 lists those with records spanning 10 or more years. The Rio Chama stations are incorporated into the surface water analysis because processes on this river affect how SJC Project water is used in the planning region (see Section 5.3.3). Stations outside of the planning region are assigned to arbitrarily named regions that include the Rio Chama, Western Estancia, and Albuquerque basins.

Statistical analyses have been performed on the monitored streamflow from USGS gaging stations with 10 or more years of daily records; 26 of the 61 stations initially identified by Duke fall into this category (Duke, 2001). Table 9 presents statistical summaries for annual flow. Table 10 presents exceedance probabilities for annual flows, and Table 11 presents daily flows. The range in monitored flows at most of the stations is quite large.

Not every sub-basin in the Jemez y Sangre planning region has had flow monitored on its tributaries to the Rio Grande. Velarde Sub-Basin has not been monitored, and the Caja del Rio and North Galisteo Creek Sub-Basins are essentially ungaged, since only peak flows have been monitored on one watercourse in each sub-basin for limited periods of time. An estimate of the annual tributary inflow in ungaged areas was necessary to develop water budgets for all sub-basins. Duke elected to use the Reiland (1975) method to estimate the mean annual long-term streamflow from ungaged watersheds because of its simplicity and project time constraints. The Reiland method uses a simple runoff-versus-elevation relationship based on the principles that average annual precipitation typically increases with elevation whereas temperature and PET



Source: Duke, 2001 (Figure 3-4)

JEMEZ Y SANGRE REGIONAL WATER PLAN

USGS Stream Gaging Stations

Figure 11

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Table 9. Statistical Summary of Annual Flows at Gaging Stations

Station Number	Station Name	Period of Record	Annual Flow (cubic feet per second) [a]					
			Minimum	Maximum	Mean	Median	Standard Deviation	Coefficient of Variation
8279500	Rio Grande at Embudo	1912-1997	308.21	2,076.60	913.86	850.53	438.83	0.48
8281100	Rio Grande above San Juan Pueblo	1963-1986	292.35	1,644.70	808.85	807.38	388.93	0.48
8283500	Rio Chama at Park View	1930-1955	127.76	645.30	328.31	295.73	164.73	0.50
8284100	Rio Chama near La Puente	1955-1997	63.02	723.17	364.10	367.77	170.31	0.47
8285500	Rio Chama below El Vado Dam	1935-1997	147.76	823.44	421.52	396.02	181.92	0.43
8286500	Rio Chama above Abiquiu Reservoir	1961-1997	186.20	823.67	479.94	440.33	191.01	0.40
8287000	Rio Chama below Abiquiu Dam	1961-1997	199.52	872.48	506.73	490.69	178.25	0.35
8287500	Rio Chama near Abiquiu	1941-1967	178.92	1,060.70	397.33	375.31	197.75	0.50
8290000	Rio Chama near Chamita	1929-1997	159.72	1,209.90	543.54	528.41	252.44	0.46
8291000	Santa Cruz River near Cundiyo	1932-1997	8.93	75.17	31.70	27.81	16.70	0.53
8291500	Santa Cruz River at Riverside	1942-1951	1.81	19.66	9.69	8.32	7.65	0.79
8292000	Santa Clara Creek near Española	1984-1994	2.91	6.24	4.05	3.80	1.08	0.27
8294210	Rio Nambe below Nambe Falls Dam	1984-1997	7.01	25.75	15.83	15.97	5.31	0.34
8294300	Rio Nambe at Nambe Falls, Near Nambe	1963-1978	6.18	28.36	10.34	9.14	5.64	0.55
8295000	Rio Nambe near Nambe	1932-1951	3.22	28.50	10.77	9.68	6.65	0.62
8295200	Rio En Medio near Santa Fe	1963-1973	0.50	1.60	0.83	0.77	0.37	0.44
8302500	Tesuque Creek above Diversions Near Santa Fe	1936-1951	0.74	8.14	3.36	2.92	2.24	0.67
8313000	Rio Grande at Otowi Bridge	1918-1997	520.53	3,321.60	1,500.34	1,464.70	671.23	0.45
8314500	Rio Grande at Cochiti	1926-1970	454.96	3,298.40	1,301.79	1,221.65	676.36	0.52
8316000	Santa Fe River near Santa Fe	1913-1997	1.88	26.22	8.23	6.50	4.98	0.60
8317200	Santa Fe River aAbove Cochiti Lake	1970-1997	6.10	40.24	11.67	8.84	6.95	0.60
8317400	Rio Grande below Cochiti Dam	1970-1997	452.13	2,355.10	1,444.66	1,487.60	595.94	0.41
8317850	Galisteo Creek above Galisteo Reservoir	1970-1976	3.49	12.47	8.15	9.02	3.19	0.39
8317950	Galisteo Creek below Galisteo Dam	1970-1997	1.28	12.80	6.13	5.72	2.99	0.49
8318000	Galisteo Creek at Domingo	1941-1971	1.49	27.61	10.19	7.94	6.82	0.67
8319000	Rio Grande at San Felipe	1930-1997	502.65	3,401.70	1,418.86	1,344.40	674.24	0.48

Source: Duke, 2001 (Table 3-3).

[a] For stations with 10 or more years of record.

Table 10. Probability of Exceedance for Average Annual Flow at Gaging Stations

Station Number	Station Name	Period of Record	Percent of Time Flow Was Exceeded												
			99	98	90	80	70	60	50	40	30	20	10	5	1
			Average Annual Flow (cubic feet per second)												
8279500	Rio Grande at Embudo	1912-1997	283.6	297.2	385.0	473.6	589.6	737.3	872.1	989.5	1,109.4	1,268.8	1,493.8	1,759.4	2,245.0
8281100	Rio Grande above San Juan Pueblo	1963-1986	276.1	282.3	331.3	408.7	527.5	670.0	785.0	897.0	1,008.2	1,140.0	1,370.0	1,612.5	1,842.5
8283500	Rio Chama at Park View	1930-1955	113.3	116.7	143.3	175.0	207.0	242.0	283.3	350.0	418.8	497.5	591.3	685.0	785.0
8284100	Rio Chama near La Puente	1955-1997	56.7	63.4	157.5	183.8	237.3	302.0	350.0	427.0	490.0	542.5	595.0	670.0	782.0
8285500	Rio Chama below El Vado Dam	1935-1997	134.4	152.2	200.7	243.4	290.4	344.7	390.3	435.1	500.5	592.0	708.0	769.0	923.1
8286500	Rio Chama above Abiquiu Reservoir	1961-1997	168.0	186.0	230.3	274.0	346.0	396.8	446.3	508.8	576.3	661.4	764.3	839.0	1,047.8
8287000	Rio Chama below Abiquiu Dam	1961-1997	167.5	185.0	258.3	318.0	391.3	473.6	521.4	569.1	621.1	698.9	776.7	846.3	1,049.3
8287500	Rio Chama near Abiquiu	1941-1967	153.3	156.5	182.5	221.0	266.5	318.0	372.0	429.2	490.0	555.0	650.0	780.0	1,024.6
8290000	Rio Chama near Chamita	1929-1997	158.5	167.0	228.0	304.7	387.4	461.7	518.3	575.0	647.1	744.3	916.3	1,080.7	1,332.0
8291000	Santa Cruz River near Cundiyo	1932-1997	8.5	9.5	13.0	17.1	20.6	24.2	27.7	33.0	38.6	46.4	58.0	65.4	82.5
8291500	Santa Cruz River at Riverside	1942-1951	1.8	1.8	2.2	2.8	3.3	3.6	4.0	13.6	15.2	17.2	19.6	20.8	21.8
8292000	Santa Clara Creek near Española	1984-1994	2.3	2.4	2.7	3.1	3.3	3.6	3.8	4.0	4.7	5.3	6.2	6.7	7.0
8294210	Rio Nambe below Nambe Falls Dam	1984-1997	5.5	5.8	7.8	10.9	12.9	14.2	15.5	17.0	18.5	20.1	21.6	24.1	27.2
8294300	Rio Nambe at Nambe Falls, near Nambe	1963-1978	5.4	5.4	5.8	6.3	6.8	7.8	9.3	10.1	10.8	11.6	14.4	31.0	36.6
8295000	Rio Nambe near Nambe	1932-1951	3.2	3.3	3.9	5.7	6.7	8.4	9.8	10.8	11.8	13.9	23.2	29.0	36.2
8295200	Rio En Medio near Santa Fe	1963-1973	0.0	0.0	0.1	0.3	0.4	0.5	0.6	0.8	0.9	1.1	1.3	1.5	1.7
8302500	Tesuque Creek above Diversions near Santa Fe	1936-1951	0.1	0.3	1.4	1.8	2.1	2.4	2.7	3.1	3.6	4.5	7.9	8.6	9.2
8313000	Rio Grande at Otowi Bridge	1918-1997	479.8	499.5	652.2	831.1	1,039.4	1,286.7	1,497.8	1,669.6	1,841.3	2,108.0	2,424.0	2,828.0	3,510.0
8314500	Rio Grande at Cochiti	1926-1970	398.4	446.8	545.0	670.0	819.7	1,032.3	1,228.6	1,416.7	1,600.0	1,783.3	2,140.0	2,470.0	3,124.0
8316000	Santa Fe River near Santa Fe	1913-1997	2.2	2.4	3.4	4.3	4.9	5.7	6.8	8.1	9.7	11.7	16.8	20.2	25.6
8317200	Santa Fe River above Cochiti Lake	1970-1997	5.4	5.5	6.1	6.9	7.7	8.4	9.2	12.1	13.9	15.7	19.5	21.5	46.8
8317400	Rio Grande below Cochiti Dam	1970-1997	379.7	409.4	678.0	786.0	962.3	1,220.0	1,493.8	1,662.5	1,831.3	2,037.1	2,268.6	2,384.3	2,476.9
8317850	Galisteo Creek above Galisteo Reservoir	1970-1976	3.2	3.2	3.6	5.7	6.7	7.5	8.2	8.9	9.8	11.5	13.6	14.8	15.8
8317950	Galisteo Creek below Galisteo Dam	1970-1997	1.1	1.2	2.6	3.4	3.8	5.2	5.9	6.6	7.5	8.7	10.5	11.7	14.9
8318000	Galisteo Creek at Domingo	1941-1971	1.4	1.5	2.7	3.6	5.1	7.4	8.6	12.3	14.2	16.3	20.7	23.7	27.1
8319000	Rio Grande at San Felipe	1930-1997	476.8	493.5	625.6	774.4	957.9	1,149.1	1,331.8	1,516.7	1,702.8	1,888.9	2,278.0	2,479.0	3,965.0

Source: Duke, 2001 (Table 3-8)

Table 11. Statistical Summary of Daily Flows at Gaging Stations

Station Number	Station Name	Period of Record	Daily Flow (cubic feet per second) [a] Minimum	Maximum	Mean	Standard Deviation	Coefficient of Variation
8279500	Rio Grande at Embudo	1912-1997	165.00	13,900.00	912.92	1,184.41	1.30
8281100	Rio Grande above San Juan Pueblo	1963-1986	95.00	7,850.00	796.60	924.84	1.16
8283500	Rio Chama at Park View	1930-1955	1.30	7,030.00	328.12	694.66	2.12
8284100	Rio Chama near La Puente	1955-1997	4.40	7,720.00	363.86	733.79	2.02
8285500	Rio Chama below El Vado Dam	1935-1997	0.00	6,010.00	423.57	623.54	1.47
8286500	Rio Chama above Abiquiu Reservoir	1961-1997	7.60	6,480.00	478.50	687.04	1.44
8287000	Rio Chama below Abiquiu Dam	1961-1997	8.80	2,780.00	506.53	555.06	1.10
8287500	Rio Chama near Abiquiu	1941-1967	1.00	5,330.00	397.11	549.50	1.38
8290000	Rio Chama near Chamita	1929-1997	0.00	8,760.00	543.26	743.30	1.37
8291000	Santa Cruz River Near Cundiyo	1932-1997	1.10	623.00	31.69	45.12	1.42
8291500	Santa Cruz R at Riverside	1942-1951	0.00	594.00	14.03	48.04	3.42
8292000	Santa Clara Creek near Española	1984-1994	0.00	29.00	4.01	2.78	0.69
8294210	Rio Nambe below Nambe Falls Dam	1984-1997	0.00	112.00	16.10	19.79	1.23
8294300	Rio Nambe at Nambe Falls, near Nambe	1963-1978	0.30	138.00	10.02	12.30	1.23
8295000	Rio Nambe near Nambe	1932-1951	0.10	152.00	10.57	15.00	1.42
8295200	Rio En Medio near Santa Fe	1963-1973	0.20	9.50	0.82	0.96	1.18
8302500	Tesuque Creek above Diversions Near Santa Fe	1936-1951	0.00	72.00	3.23	5.22	1.62
8313000	Rio Grande at Otowi Bridge	1918-1997	106.00	22,200.00	1,499.61	1,826.16	1.22
8314500	Rio Grande At Cochiti	1926-1970	1.00	22,400.00	1,300.16	1,737.22	1.34
8316000	Santa Fe River near Santa Fe	1913-1997	0.10	378.00	8.32	13.41	1.61
8317200	Santa Fe River above Cochiti Lake	1970-1997	0.00	1,000.00	11.51	30.23	2.63
8317400	Rio Grande below Cochiti Dam	1970-1997	0.51	8,290.00	1,443.92	1,478.49	1.02
8317850	Galisteo Creek above Galisteo Reservoir	1970-1976	0.01	873.00	8.79	40.85	4.65
8317950	Galisteo Creek below Galisteo Dam	1970-1997	0.00	1,170.00	6.32	35.42	5.60
8318000	Galisteo Creek at Domingo	1941-1971	0.00	4100.00	9.93	87.86	8.85
8319000	Rio Grande at San Felipe	1930-1997	34.00	21,300.00	1418.17	1,658.55	1.17

Source: Duke, 2001 (Table 3-5).

[a] For stations with 10 or more years of record.

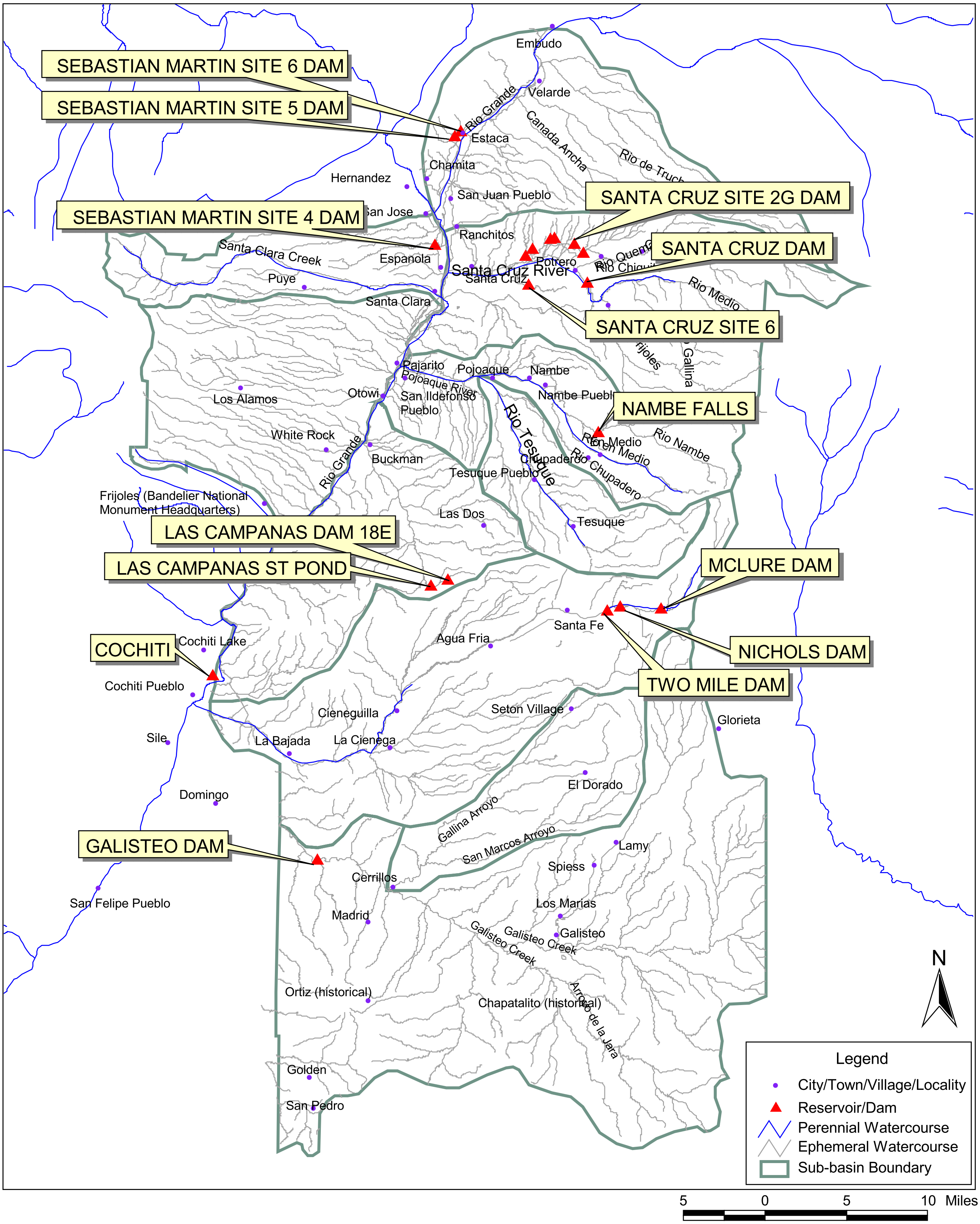
decrease. Because streamflow is generated where precipitation exceeds evapotranspiration, there is typically greater streamflow per unit area as elevation increases. Reiland (1975) applied his methodology specifically to the Pojoaque River watershed, and developed average streamflow values per unit land area for elevation intervals that occurred within the watershed.

5.2.3 Reservoirs and Lakes

Major dams and associated reservoirs in the planning region, which represent existing surface-water storage, are shown on Figure 12. Table 12 summarizes characteristics of dams and associated reservoirs, and also includes descriptions of dams and reservoirs that are either located a short distance outside the planning boundary or have some bearing on potential water supply of the region. Included in this latter category are surface-water storage entities that may influence SJC water diverted to the Rio Chama drainage. Two Mile Dam, which is listed in Table 12 and shown on Figure 12, was breached in 1994 due to dam instability. The capacity of the Two Mile Reservoir was transferred to McClure Dam once the height of the McClure Dam had been raised.

As Table 12 indicates, with the exception of Cochiti Reservoir on the main stem Rio Grande, the largest storage reservoirs in the planning region are Santa Cruz Lake on the Santa Cruz River, Nambe Falls Reservoir on the Rio Nambe, and McClure Reservoir on the Santa Fe River. Inflows and outflows from reservoirs vary seasonally and annually. Storage levels may drop considerably during particularly dry years (e.g., 1989 and 1996); however, reservoirs eventually recover once normal precipitation returns.

In addition to providing a storage benefit, reservoirs in the region may also provide flood control benefits. Reservoirs in the region generally fill when the snowpack melts in May and June. Historically, spring thaw was a time of flooding; today, the presence of reservoirs typically prevents flooding. However, if an extreme precipitation or snowmelt event occurs when reservoirs are already full, over-dam flooding could result. This would be of greatest concern at Nichols and McClure Reservoirs, which are located just above the City of Santa Fe.



Source: Duke, 2001 (Figure 3-5)

JEMEZ Y SANGRE REGIONAL WATER PLAN

Reservoir and Dam Locations

Figure 12

Table 12. Major Dams and Reservoirs in and near the Planning Region
Page 1 of 4

Corps ID	Dam Name	Latitude	Longitude	Section	County	River	Owner Type	Use	Year Completed	Maximum Discharge (cfs)	Maximum Storage (ac-ft)	Normal Storage (ac-ft)	Surface Area (acre)	Drainage Area (mi^2)
NM00179	Kinsell Reservoir Dam	35.1383	-105.8883	T11N R10E S32	Santa Fe	Armijo Draw-Tr	P	I	1911	0		574		0
NM00241	Nichols Dam	35.7133	-105.8797	T17N R10E S21	Santa Fe	Santa Fe River	U	WS	1943	19,690	943	685	39	22
NM00242	Mcclure Dam	35.6950	-105.8333	T17N R10E S24	Santa Fe	Santa Fe River	U	WS	1926	16,100	3,770	2,700	77	17
NM00251	Santa Cruz Dam	35.9833	-105.9167	T20N R10E S27	Santa Fe	Santa Cruz River	P	I,R	1929	22,000	3,700		115	99
NM00561	Santa Cruz Watershed Site 6	35.9767	-105.9850	T20N R9E S9	Santa Fe	Santa Cruz River-Tr	P	D	1984	7,134	1,730	0	76	3
NM00547	Las Campanas Dam 18e	35.7167	-106.0583	T17N R8E S11	Santa Fe	Off Channel Reservoir	P	R	1992	840	58	31	4.9	0.92
NM00559	Las Campanas Effluent Storage Pond	35.7042	-106.0833	T17N R8E S15	Santa Fe		P	R		2	30		3	
NM00357	Two Mile Dam	35.6883	-105.8933	T17N R10E S10	Santa Fe	Santa Fe River-Os	U	S	1894	18,200	605	387	23	27
NM00412	Nambe Falls	35.8458	-105.9092		Santa Fe	Rio Nambe River	F	I,R, FW	1976	22,500	2883	2023	74	35
NM00002	Galisteo Dam	35.4617	-106.2083	T14N, R7E, S9	Santa Fe	Galisteo Creek	F	C,O	1970	90,000	152,600	0	1	596

Source: Duke, 2001 (Table 3-9)
ac-ft = Acre-feet
cfs = Cubic feet per second
mi^2 = Square miles

Owner Type:
F = Federal
S = State
L = Local government
U = Public utility
P = Private

Usage:
C = Floor control/storm water management
H = Hydroelectric
I = Irrigation
N = Navigation
WS = Water supply
R = Recreation
FW = Fish and wildlife pond
DI = Debris control
T = Tailings
O = Other

Table 12. Major Dams and Reservoirs in and near the Planning Region
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Corps ID	Dam Name	Latitude	Longitude	Section	County	River	Owner Type	Use	Year Completed	Maximum Discharge (cfs)	Maximum Storage (ac-ft)	Normal Storage (ac-ft)	Surface Area (acre)	Drainage Area (mi^2)
NM00264	Santa Cruz Site 6	35.9767	-105.9850		Santa Fe	Alamo Arroyo Tr-Santa Cruz	L	C,O	1984	7,134	1,352	628	0	3.1391
NM00173	Wp Johnson Erosion Ctrl	35.8850	-107.1567	T19N R3W S9	Sandoval	Jariado Arroyo	P	C	1945	616		124	34.7	17.89
NM00404	Cochiti	35.6250	-106.3333	T16N, R6W, S16	Sandoval	Rio Grande & Santa Fe	F	C,R, O,I	1975	136360	722000	50130	1200	14635
NM00127	El Vado Reservoir Dam	36.5933	-106.7333	T28N R2E S33	Rio Arriba	Rio Chama	P	I,R	1935	33500		219580		873
NM00262	Santa Cruz Site 4 Dam	36.0100	-105.9800	T21N R9E S34	Rio Arriba	Martinez Arroyo	P	C	1962	4898.6	322	0	29	2
NM00260	Santa Cruz Site 1 Dam	36.0083	-105.9167	T21N R10E S31	Rio Arriba	Cañada Ancha	P	C	1962	7298	963	0	43	8
NM00238	Santa Cruz Site 3a Dam	36.0200	-105.9533	T21N R9E S26	Rio Arriba	Santa Cruz River - Tributary	P	C	1972	6270	1610	0	60	2.2
NM00234	Sebastian Martin Site 6 Dam	36.1000	-106.0500	T22N R8E S26	Rio Arriba	Estaca Arroyo	P	C	1973	0	1022	0	45	2
NM00261	Santa Cruz Site 2g Dam	36.0133	-105.9367	T21N R9E S36	Rio Arriba	Arroyo De Los Encinos	P	C	1985	4730	1096	0	52.5	2
NM00263	Santa Cruz Site 5 Dam	36.0033	-105.9867	T21N R9E S33	Rio Arriba	Morada Arroyo	P	C	1962	3442	192	0	13	1
NM00237	Santa Cruz	36.0183	-105.9550	T21N R9E S26	Rio Arriba	Cañada De	P	C	1972	170	470	0	30	0.37

Source: Duke, 2001 (Table 3-9)
ac-ft = Acre-feet
cfs = Cubic feet per second
mi^2 = Square miles

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Table 12. Major Dams and Reservoirs in and near the Planning Region
Page 3 of 4

Corps ID	Dam Name	Latitude	Longitude	Section	County	River	Owner Type	Use	Year Completed	Maximum Discharge (cfs)	Maximum Storage (ac-ft)	Normal Storage (ac-ft)	Surface Area (acre)	Drainage Area (mi^2)
	Site 3 Dam					Los Ramones								
NM00233	Sebastian Martin Site 5 Dam	36.1067	-106.0650	T22N R8E S26	Rio Arriba	Arroyo De Lopez	P	C	Unknown	1469	460	0	24	1
NM00441	Sebastian Martin Site 4 Dam	36.1033	-106.0700	T21N R8E S34	Rio Arriba	Arroyo De Borregos	P	C	1977	2713	691	0	36	1
NM00122	Heron	36.6661	-106.7100		Rio Arriba	Willow Creek	F	WS,I	1971	660	429646	401317	6148	193
NM00123	Heron Dike	36.6717	-106.7200		Rio Arriba	Willow Creek Tr	F	WS,I	1971		429646	401317	6148	193
NM10008	El Vado	36.5933	-106.7467		Rio Arriba	Rio Chama	F	I, R, WS	1935	17800	209330	186250	3360	492
NM00001	Abiquiu Dam	36.2400	-106.4300	T23N, R5E, S8	Rio Arriba	Rio Chama	F	C,I,WS,O	1963	25000	1369000	170000	3900	2146
NM00438	Sebastian Martin-Black Mesa Site 1	36.0817	-106.0817	T21N,R8E,S8	Rio Arriba	Trib To Rio Grande	L	C,O	1978	1927	280	110	0	0.5594
NM00439	Sebastian Martin-Black Mesa Site 2	36.0900	-106.0783		Rio Arriba	Arroyo Del Guique Tr-Rio Grand	L	C,O	1977	636	152	48	0	0.2094
NM00440	Sebastian Martin-Black Mesa Site 3	36.0967	-106.0733		Rio Arriba	San Rafael Tr-Rio Grande	L	C,O	1977	1190	151	76	0	0.3094

Source: Duke, 2001 (Table 3-9)
ac-ft = Acre-feet
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Table 12. Major Dams and Reservoirs in and near the Planning Region
Page 4 of 4

Corps ID	Dam Name	Latitude	Longitude	Section	County	River	Owner Type	Use	Year Completed	Maximum Discharge (cfs)	Maximum Storage (ac-ft)	Normal Storage (ac-ft)	Surface Area (acre)	Drainage Area (mi^2)
NM00518	Sebastian Martin-Black Mesa Site 18	36.1383	-106.0683		Rio Arriba	Trib. To Rio Grande	L	C	1985	1666	235	67	0	0.95
NM83401	Los Alamos	35.8417	-106.3731		Los Alamos	Los Alamos Cr	F	WS	1943	600	49	41	3	5
NM00299	Doe Los Alamos Canyon Dam	35.8417	-106.3731		Los Alamos	Los Alamos Cr	F	WS	1938	600	49	41	3	5

ac-ft = Acre-feet
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A draft Environmental Impact Statement (EIS), prepared in regard to City of Santa Fe drinking water projects, included an evaluation of the flood control storage in Nichols and McClure Reservoirs. The EIS, which considered an earlier Federal Emergency Management Agency study in evaluating flood potential below McClure and Nichols, concluded that the reservoirs do not provide sufficient flood control storage to provide protection from extreme runoff or flood events.

5.2.4 Irrigated Agriculture

Irrigated agriculture is an important component of the surface water system within the Jemez y Sangre region. Numerous acéquias within the region divert surface water to irrigate crops. Duke (2001) summarized irrigated acreage within the region (Table 13) and estimated irrigation diversions, depletions, and return flows (Table 14). The estimated irrigated acreage within the region was developed using several sources, including planning documents, LANDSAT imagery, and OSE data, as shown on Table 13.

The methods of Wilson and Lucero (1997) were used to apportion surface water diversions into depletions and return flows, as shown on Table 14. The diversion quantities shown in Table 14 represent an irrigation application rate, which was defined as consumptive irrigation requirement (CIR) divided by the product of the on-farm irrigation efficiency and off-farm conveyance efficiency. Most of the CIR values used were from Wilson and Lucero (1997), although the CIR values for the Pojoaque-Nambe and Tesuque Sub-Basins were taken from a court order issued under the Aamodt water rights adjudication case (U.S. District Court, 1994). Total depletions were calculated by multiplying the appropriate CIR by the irrigated acreage, and augmenting the resulting product by a fraction reflective of cumulative incidental losses. Return flows, which were assumed to go back to the natural drainage system, were determined by subtracting total depletions from irrigation diversions. In addition to surface-water computations, Table 14 lists analogous groundwater budget values associated with irrigation.

Table 13. Irrigated Acreage Estimates for the Planning Region

Sub-Basin	Irrigated Acreage by Information Source			
	Rio Arriba County Planning Office	1992-Landsat Image	Wilson and Lucero (1997)	Hydrographic Survey
Velarde				
Velarde Area	1815	3176	2870	NA
Rio de Truchas Area	3258	334	2925	2064.3 [a]
Velarde Total	*5073*	*3510*	*5795*	*2064.3*
Santa Cruz				4780 [a]
Rio Arriba County	1326	1010	4155	NA
Santa Fe County		910	5735	NA
Santa Cruz Total	*1326*	*1920*	*9888*	*4780*
Santa Clara	699	545	NA	NA
Los Alamos		0	0	0
Pojoaque-Nambe		957	2375 [c]	3538 [b,c]
Tesuque		170	0 [d]	0 [d]
Caja del Rio		0	0	0
Santa Fe River		306	965	485 [e]
North Galisteo Creek		0	0	0
South Galisteo Creek		88	0	0

[a] Hydrographic survey conducted during 1970.
[b] Hydrographic survey conducted during 1966.
[c] Includes Tesuque estimate
[d] Included in Pojoaque-Nambe estimate
[e] Hydrographic survey conducted during 1976.

Source: Duke, 2001 (Table 3-12)
NA = not available.

Table 14. Estimated Irrigation Diversions, Depletions, and Return Flows

Sub-Basin	Irrigated Land[a] (acres)		Consumptive Irrigation Requirement[a] (ft/yr)		On-Farm Irrigation Efficiency[a] (dimensionless)		Off-Farm Conveyance Efficiency[a] (dimensionless)		Total Diversion[b] (afy)		Incidental Depletion Fraction[a] (dimensionless)		Total Depletion[c] (afy)		Return Flow[d] (afy)	
	Surface Water	Ground-water	Surface Water	Ground-water	Surface Water	Ground-water	Surface Water	Ground-water	Surface Water	Ground-water	Surface Water	Ground-water	Surface Water	Ground-water	Surface Water	Ground-water
Velarde																
Velarde and Vicinity	2,835	35	1.807	1.122	0.5	0.85	0.7	0	14,637	46	0.168	0	5,983	39	8,653	7
Rio de Truchas	2,925	0	1.126	0	0.4	0	0.7	0	11,763	0	0.113	0	3,666	0	8,097	0
Subtotal	5,760	35	2.933	1.122	0.9	0.85	1.4	0	26,400	46	0.281	0	9,649	39	16,750	7
Santa Cruz																
Rio Arriba County	4,155	0	0.894	0	0.55	0	0.7	0	9,648	0	0.179	0	4,379	0	5,269	0
Santa Fe County	5,735	0	0.675	0	0.55	0	0.7	0	10,055	0	0.179	0	4,564	0	5,491	0
Subtotal	9,890	0	1.569	0	1.1	0	1.4	0	19,703	0	0.358	0	8,943	0	10,760	0
Santa Clara	699[e]	0	0.894	0	0.55	0	0.7	0	1,623	0	0.179	0	737	0	886	0
Los Alamos	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pojoaque-Nambe	1,900[f]	120	1.84[f]	1.678	0.55	0.55	0.7529	0.7529	8,442	366	0.14	0.11	3,985	224	4,457	143
Tesuque	475[h]	0	1.84 h	1.678	0.55	0.55	0.7529	0.7529	2,111	0	0.14	0.11	996	0	1,115	0
Caja del Rio	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Santa Fe River																
Drip Irrigation	0	20	0	0.938	0	0.85	0	0	0	22	0	0	0	19	0	3
Flood Irrigation	815	130	1.14	1.14	0.5	0.5	0.7	0.7	2,655	296	0.179	0.15	1,095	170	1,559	126
Subtotal	815	150	1.14	2.078	0.5	1.35	0.7	0.7	2,655	318	0.179	0.15	1,095	189	1,559	129
North Galisteo Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Galisteo Creek	88[j]	0	1.14	0	0.5	0	0.7	0	287	0	0.179	0	118	0	168	0

Source: Duke, 2001 (Table 3-13).
ft/yr = Feet per year afy = Acre-feet per year CIR = Consumptive irrigation requirement
[a] Unless noted otherwise, values taken from Wilson and Lucero (1997).
[b] Total diversion = (irrigated acreage x CIR)/[(on-farm irrigation efficiency) x (off-farm irrigation efficiency)].
[c] Total depletion = (irrigated acreage x CIR) x (1 + incidental depletion fraction).
[d] Return flow = total diversion – total depletion.
[e] Irrigated acreage in the Santa Clara sub-basin from estimate by the Rio Arriba County Planning Office.
[f] Irrigated acreage in the Pojoaque-Nambe Sub-Basin assumed equal to 80% of Wilson and Lucero (1997) estimate for combined area of Pojoaque-Nambe and Tesuque Sub-basins.
[g] Consumptive irrigation requirement in the Pojoaque-Nambe Sub-Basin based on an Order of the Court in the Aamodt adjudication case. (U.S. District Court, 1994).
[h] Irrigated acreage in the Tesuque sub-basin assumed equal to 20% of Wilson and Lucero (1997) estimate for combined area of Pojoaque-Nambe and Tesuque Sub-Basins.
[i] Irrigated acreage in South Galisteo Creek Sub-Basin estimated from 1992 Landsat image.

5.2.5 San Juan-Chama Project

The SJC Project, authorized as part of the Colorado River Storage Project, provides an average annual diversion of about 110,000 acre-feet of water from the upper tributaries of the San Juan River for use in the Rio Grande Basin of New Mexico. Some of this additional water is used for municipal, domestic, industrial, and agricultural purposes within the Jemez y Sangre planning region. The contracted quantities of SJC water within the planning region include:

- City and County of Santa Fe: 5,605 acre-feet
- County of Los Alamos: 1,200 acre-feet
- City of Española: 1,000 acre-feet
- PVID: 1,030 acre-feet
- San Juan Pueblo: 2,000 acre-feet

In addition, an annual allocation of SJC water is available to the USACE for its operation of Cochiti Reservoir. The intent is to compensate for evaporation losses and maintain a minimum surface area of 1,200 acres for the reservoir. The various entities that use SJC water contract for their respective supplies with the Bureau of Reclamation. Presently, not all contracting entities in the region are using their allocation of SJC water. SJC water is used by the City of Santa Fe to offset pumping from the Buckman well field and by the PVID to offset diversions from Pojoaque Creek. Additional analysis of the SJC Project is included Section 7, *Alternative Approaches and Scenarios to Close Supply/Demand Gap*, and in Appendix F.

5.3 Groundwater Supply

This section summarizes the groundwater supplies in the Jemez y Sangre Water Planning Region and the general characteristics of hydrogeologic units in the Española Basin, including both water-bearing aquifers and relatively impermeable units.

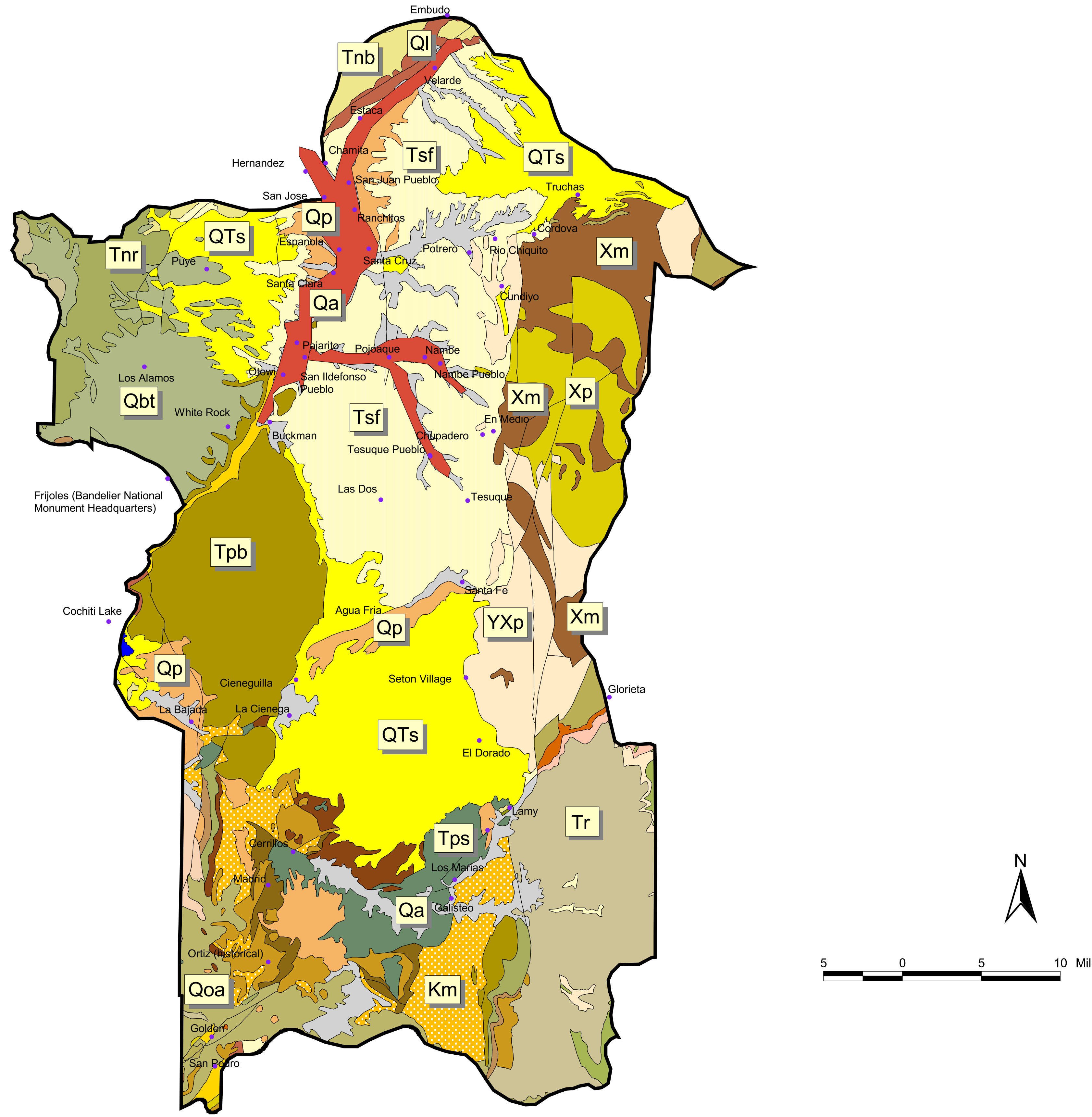
The evaluation of groundwater resources draws on diverse forms of data, with particular attention paid to the locations and characteristics of the numerous wells found in the region's hydrogeologic units. Types of wells included in the discussion range from monitoring wells maintained by the USGS to irrigation and municipal supply wells. Groundwater level hydrographs from many of the wells are presented as are pumping records from wells with recorded discharges. Accompanying figures portray the spatial distribution of aquifers, groundwater levels and associated hydraulic gradients, and distribution of groundwater withdrawals.

This section was compiled using information obtained primarily from the Duke study (2001). To develop an understanding of both regional and local geology, Duke relied on reports from the USGS, the New Mexico Bureau of Mines and Mineral Resources, and LANL. Information regarding the major aquifer systems in the planning region, as well as other less transmissive hydrogeologic units, was obtained from government agency and consulting reports that address groundwater flow conditions throughout the region. To develop conceptual models of groundwater flow and storage, Duke used the previously mentioned sources as well as several groundwater modeling studies (past and ongoing).

5.3.1 Regional Hydrogeology

The Jemez y Sangre Water Planning Region lies within the Española Basin (Kelley, 1977). This structural geologic basin is centered near the City of Española, on the confluence of the Rio Grande with its principal tributary, the Rio Chama. The basin encompasses the Española Valley, which is generally considered to comprise the lower-lying areas within the structural basin. The Sangre de Cristo Mountains form the eastern boundary of the basin, and the Jemez Mountains the western boundary.

Figure 13 illustrates the surface geology of the planning region, as presented in Green and Jones (1997). The Sangre de Cristo Mountains in the eastern part of the planning region are covered by Precambrian rocks, which are inferred to exist under the entire study area. The Precambrian rocks have relatively low permeability and storage capacity, but can transmit water though fractures to overlying younger sediments. Paleozoic rocks are found intermittently along the west flank of the Sangre de Cristo Mountains; however, most of the sediments lying within the Española Basin comprise the geologic unit known broadly as the Santa Fe Group. This



	Tr	Chinle formation
	Jm	Morrison formation
	Kd	Dakota formation
	Km	Mancos Shale; divided by Gallup Sandstone
	Kmv	Mesaverde formation
	Pg	Glorieta sandstone
	Psa	San Andres formation
	Py	Yeso formation
	QTs	Upper Santa Fe Group
	Qa	Alluvium; upper and middle Quarternary
	Qbt	Bandelier Tuff; Jemez Mountains area only
	Ql	Landslide deposits and colluvium
	Qoa	Older alluvial deposits of upland plains and piedmont area
	Qp	Piedmont alluvial deposits; upper and middle Tertiary
	Tnb	Basalt and andesite, interbedded with Santa Fe and Gila Groups
	Tnr	Silicic to intermediate volcanic rocks; Neogene
	Tos	Espinaso formation
	Tpb	Basalt and andesite flows; Pliocene
	Tps	Paleogene sedimentary units
	Tsf	Lower and middle Santa Fe Group
	Xm	Lower Proterozoic metamorphic volcanic and volcanoclastic rocks
	Xp	Lower Proterozoic plutonic rocks
	YXp	Middle and lower Proterozoic plutonic rocks, undivided

Source: Duke, 2001 (Figure 5-1)

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JEMEZ Y SANGRE REGIONAL WATER PLAN

Regional Surface Geology

Figure 13

group consists primarily of the Tesuque, Puye, and Ancha Formations. A cross section illustrating the relationship of units within the Santa Fe aquifer system is presented in Figure 14.

Permian and Mesozoic rocks outcrop south of the Santa Fe River watershed, within the North Galisteo Creek and South Galisteo Creek Sub-Basins. Lower and middle Tertiary units, consisting of the Galisteo Formation and extrusive and intrusive rocks, are exposed in the southern part of the Jemez y Sangre planning area. The Galisteo Formation consists of sandstone, mudstone, and conglomerate (Kelley, 1978). Typically, the Galisteo and associated igneous units, along with the Permian and Mesozoic formations in the area, have low permeability and form a bedrock floor that controls the accumulation and movement of groundwater in overlying sediments (Spiegel and Baldwin, 1963).

The Tertiary Tesuque Formation of the Santa Fe Group consists of reddish-brown and pinkish-tan silty sand and gravel derived largely from the Sangre de Cristo Mountains (Spiegel and Baldwin, 1963). With a thickness of more than 9,000 feet near the Rio Grande (Kelley, 1978), the Tesuque is the principal groundwater-bearing unit in the planning region and is sometimes referred to as the Tesuque Formation aquifer. The Tesuque Formation consists of interbedded layers of gravel, sand, silt, and clay with some intercalated volcanic ash beds. Because of its stratification and the dipping of its sedimentary beds, the aquifer is considered anisotropic, with the primary hydraulic conductivity direction occurring along its bedding planes. Horizontal flow is faster than downward flow.

The Puye Formation of the Santa Fe Group is present on the western side of the Rio Grande (Griggs, 1964; Purtymun and Johanson, 1974) and is covered by Bandelier Tuff in the Jemez Mountains area. It consists of poorly sorted boulders, cobbles, and coarse sands (Spell et al., 1990). The thickness of the Puye formation varies from 60 feet near Otowi to more than 700 feet in Santa Clara Canyon (McAda and Wasiolek, 1988). The Puye Formation, which is generally underlain by the Tesuque Formation, also contains groundwater; however its occurrence is poorly characterized

The Ancha Formation of the Santa Fe Group occurs north of South Galisteo Creek, particularly within the North Galisteo Creek and Santa Fe River Sub-Basins. The Ancha is more permeable

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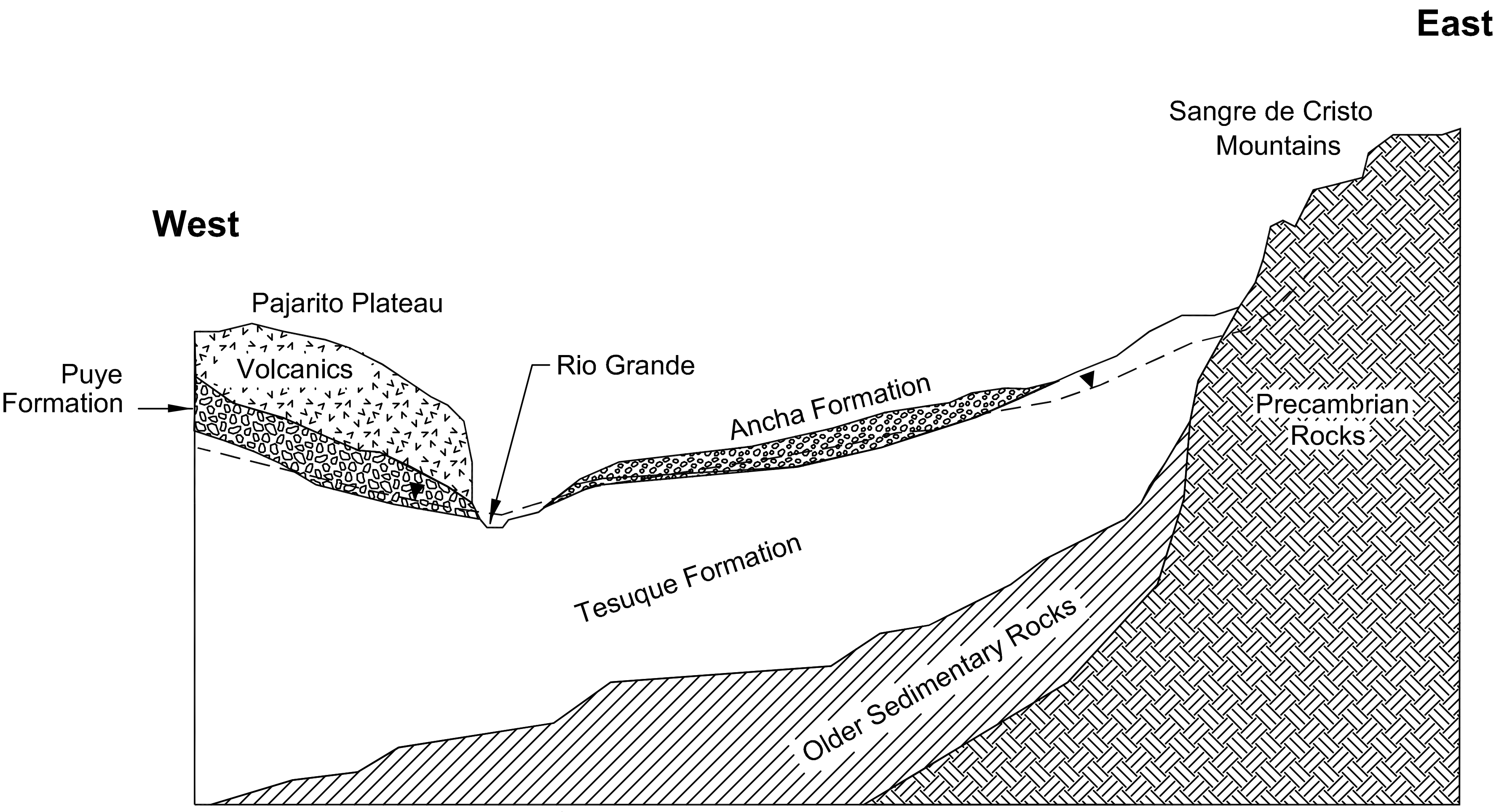


Source: DBS&A, 1994

Not to scale

JEMEZ Y SANGRE REGIONAL WATER PLAN

Schematic East-West Cross Section of the North Santa Fe County Aquifer System

Figure 14

than the Tesuque formation and is as thick as 300 feet in some areas. In most locales, the Ancha Formation is above the water table; however, when the formation is underlain by a low permeability unit it can accumulate water.

Shallow alluvial deposits, younger than the Santa Fe Group, lie beneath and adjacent to the Rio Grande and its main tributaries throughout the planning region. These deposits are better sorted and have a larger average grain size than the sediments comprising the Tesuque Formation. The shallow alluvial deposits vary from about two miles wide along the Rio Grande to less than a few hundred feet wide along the tributaries (see Figure 4, Section 3). The deposits are at least 55 feet thick along the Rio Grande (Galusha and Black, 1971) and less than 100 feet thick along the tributaries (Hearne, 1985).

5.3.2 Aquifer Characteristics

This section presents a brief discussion of the aquifer parameters hydraulic conductivity and transmissivity. Hydraulic conductivity is a comparative measure, used to describe how much water flows through an area of 1 square foot per day (ft^2/d). Typical values for hydraulic conductivities range from 0.0028 feet per day to 28 feet per day. Transmissivity is the product of hydraulic conductivity and the saturated thickness of the aquifer. Freeze and Cherry (1979) suggest that aquifers with a transmissivity greater than 13,824 ft^2/d are “good for water well exploitation”; however, aquifers with much lower transmissivity will produce water.

The Santa Fe Group, consisting of the Tesuque, Ancha, and Puye Formations, forms the principal aquifer system in all sub-basins in the planning region, except the South Galisteo Creek Sub-Basin where the Galisteo Formation comprises the main hydrogeologic unit. Summaries of the hydraulic characteristics of groundwater-bearing units in the Española Basin were developed using hydrogeology reports for areas within the planning region (e.g., Spiegel and Baldwin, 1963; Hearne, 1985; McAda and Wasiolek, 1988; DBS&A, 1994; Frenzel, 1995; U.S. District Court, 1997).

5.3.2.1 Hydraulic Conductivity and Transmissivity

Analysis of aquifer test data (DBS&A, 1994) indicates that the transmissivity of the Santa Fe Group aquifer system varies from 0.05 ft^2/d to 10,960 ft^2/d. Hydraulic conductivity is greater in the upper portion of the Santa Fe Group than in the lower portions of the group. Estimates of hydraulic conductivity for the upper portion (Ancha Formation) range from 3 feet per day to 21 feet per day. Transmissivity estimates range from 300 ft^2/d to 2,100 ft^2/d.

Hearne (1985) estimated that the hydraulic conductivity in the lower portion of the Santa Fe Group (Tesuque Formation) varies from 0.5 to 2 feet per day with a most likely value of 1 foot per day. This translates into transmissivities of 500 ft^2/d to 2,000 ft^2/d for the top 1,000 feet of the aquifer system. McAda and Wasiolek (1988) estimated the transmissivity to vary from 160 ft^2/d to 2,400 ft^2/d for the upper 800 feet of the Santa Fe Group. For very deep portions of the Santa Fe Group, transmissivities vary from 36 ft^2/d to 670 ft^2/d (McAda and Wasiolek, 1988).

Although the Ancha Formation is more permeable (higher conductivity), the Tesuque Group has substantially greater saturated thicknesses, which leads to higher transmissivities. Aquifer test data from the southern part of the planning region are too sparse to derive a hydraulic conductivity range for the Galisteo Formation. Spiegel and Baldwin (1963) reported that the conductivity of the Galisteo Formation is very low, which limits the availability of groundwater contained within it.

5.3.2.2 Groundwater Storage

Groundwater in the Santa Fe Group aquifer system is the major source of municipal and domestic supply in the planning region. Total groundwater storage in the planning region is estimated at 57.8 million acre-feet for the top 1,000 feet of the Santa Fe Group aquifer system, and 110 million acre-feet for the top 2,000 feet (Duke, 2001).

The Duke study (2001) developed estimates of groundwater in storage in the Santa Fe Group for each of the sub-basins. These estimates assumed that the aquifer system consists of a continuous, homogeneous porous medium. Although the aquifer is not homogeneous, the parameters adopted to represent a homogeneous system are believed to be generally representative of the Santa Fe Group as a whole. Storage estimates are presented in Table 15.

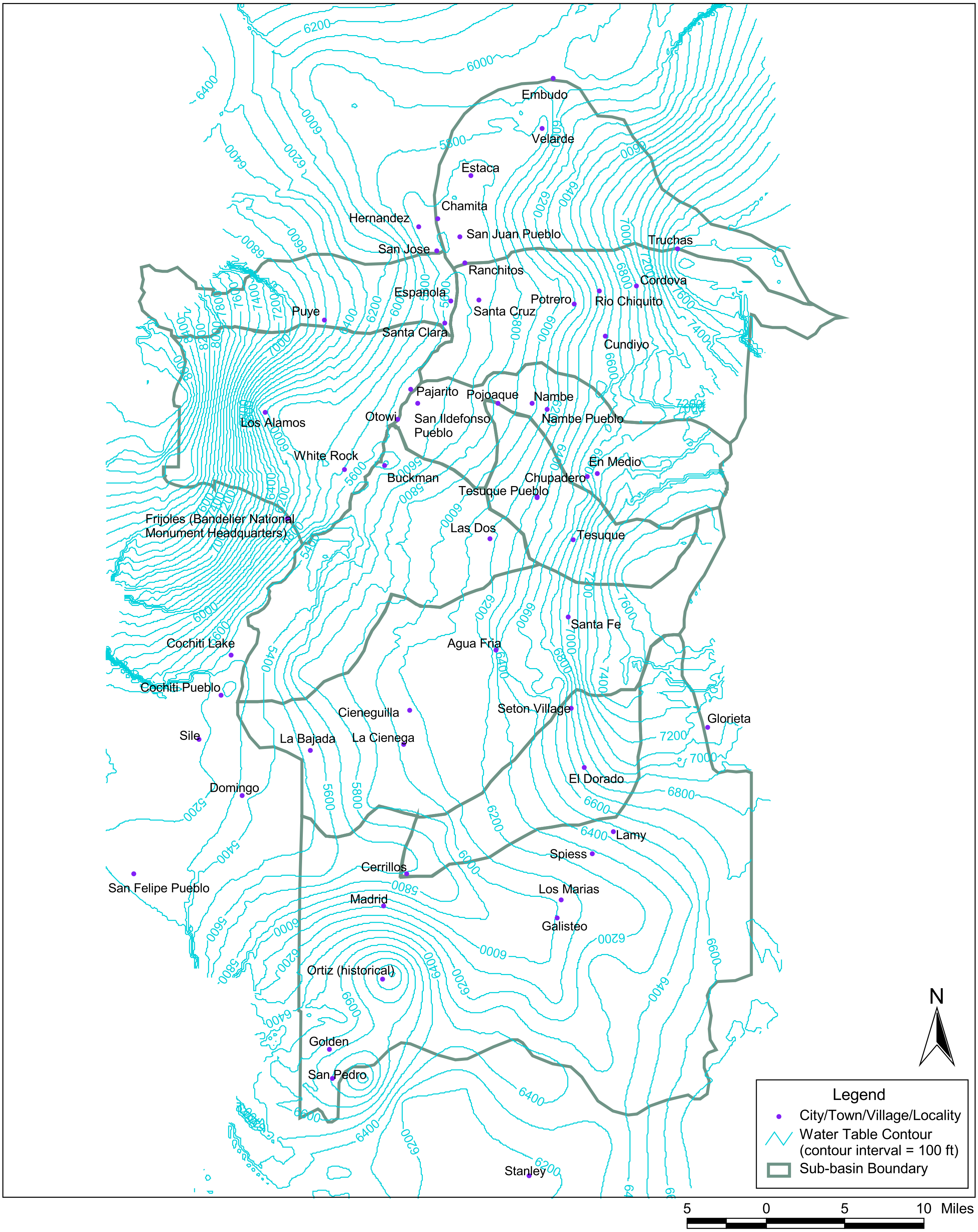
Groundwater levels and minimum and maximum saturated thicknesses listed for the Santa Fe Group in each sub-basin correspond to visual representations of this parameter shown in Figures 15 and16.

Table 15. Estimated Volume of Groundwater in Storage by Sub-Basin

Sub-Basin	Area (acres)	Santa Fe Group Saturated Thickness [a] (feet)		Storage in Aquifer [b] (million acre-feet)	
		Maximum	Minimum	Top 1,000 feet	Top 2,000 feet
Velarde	97,100	9,527	0	9.57	18.86
Santa Clara	54,600	8,983	3094	5.46	10.92
Santa Cruz	59,300	6,474	0	5.43	10.30
Los Alamos	110,200	7,921	2,058	11.02	22.04
Pojoaque-Nambe	42,500	5,096	0	3.97	7.47
Tesuque	32,400	4,463	0	2.93	5.39
Caja del Rio	101,500	3,777	1,980	10.16	20.31
Santa Fe River	111,000	2,919	0	9.26	15.08
North Galisteo Creek		0	0	0	0
South Galisteo Creek		0	0	0	0
Total				57.80	110.37

Source: Duke, 2001 (Table 5-7)
[a] Santa Fe Group saturated thickness represents the difference between post-1990 groundwater (see Figure 5-8 in Duke, 2001) and the elevation of the base of the Santa Fe Group as provided by LANL.
[b] The planning region was divided into 1,000- by 1,000-meter cells, and the volume of groundwater storage in each cell was estimated by multiplying the cell area by the local saturated thickness and an assumed specific yield of 0.1.

Table 15 indicates that the Los Alamos and Caja del Rio Sub-Basins contain the highest quantities of stored groundwater. The Santa Fe River Sub-Basin has almost the same area as the Los Alamos Sub-Basin, but contains noticeably less stored water. This is largely because the saturated thicknesses of the Santa Fe Group in the Santa Fe River Sub-Basin are generally not as large as in the Los Alamos Sub-Basin (Figure 16). The Velarde Sub-Basin contains the third largest quantities of computed groundwater storage; the total saturated thickness of the Santa Fe Group in this sub-basin approaches 9,000 feet or more.



Source: Duke, 2001 (Figure 5-8)

JEMEZ Y SANGRE REGIONAL WATER PLAN

Groundwater Level Map (Post 1990)

Figure 15

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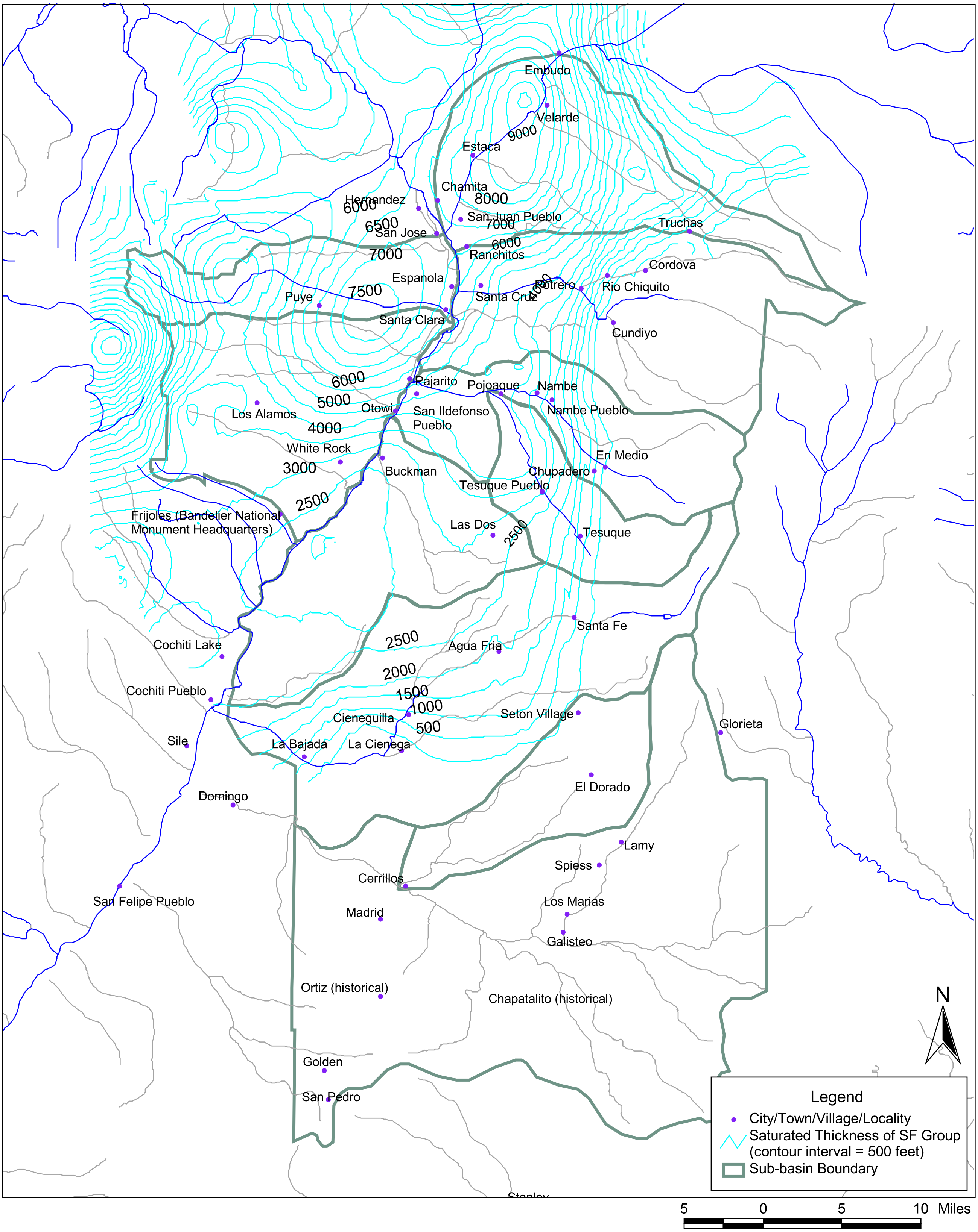

Source: Duke, 2001 (Figure 5-25)

JEMEZ Y SANGRE REGIONAL WATER PLAN

Saturated Thickness of the Santa Fe Group

Figure 16

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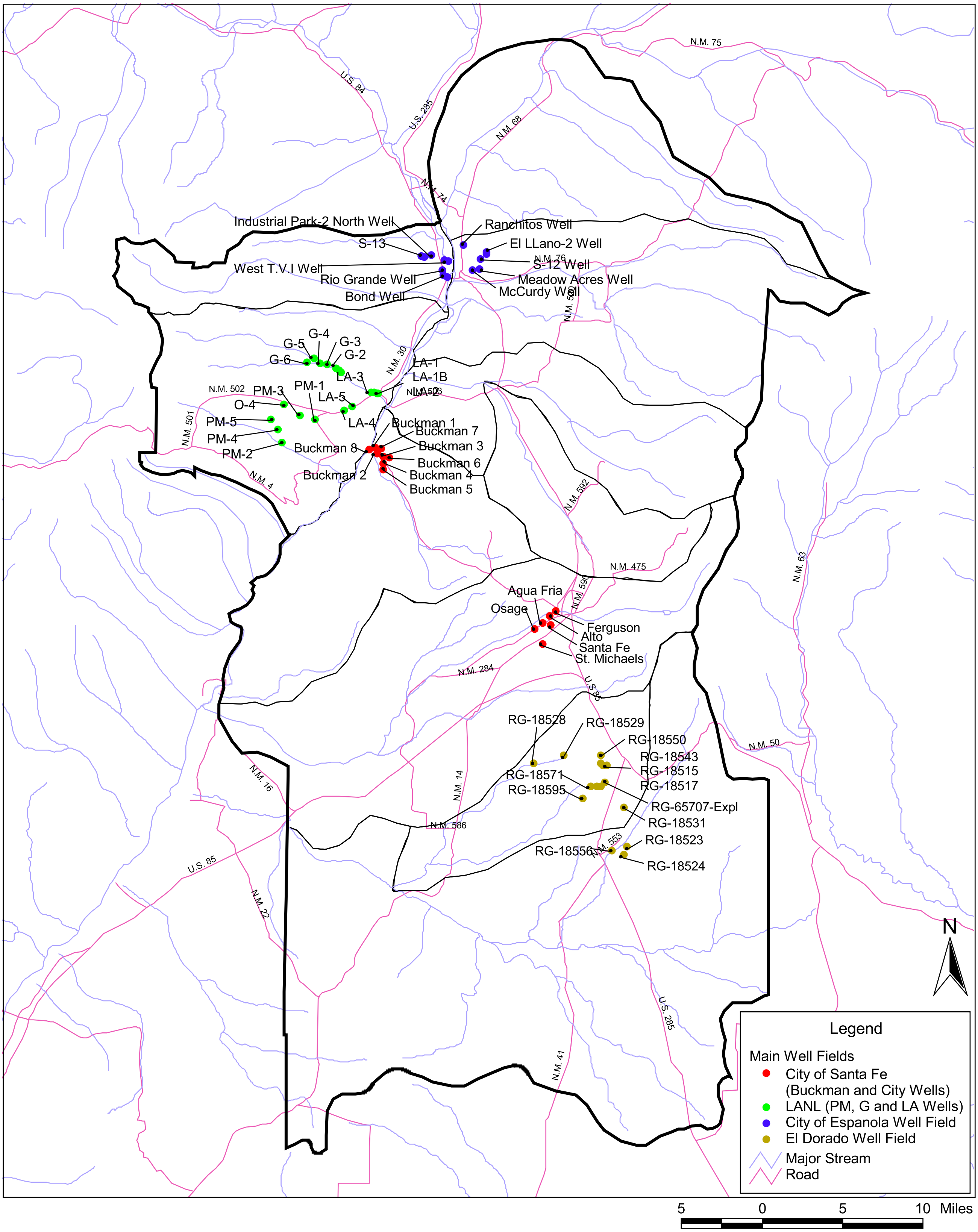
5.3.3 Well Fields

Groundwater withdrawals are used for municipal water supply in the City of Santa Fe (Buckman and City of Santa Fe well fields), Los Alamos (Los Alamos, Guaje, Pajarito Mesa, and Otowi well fields), the City of Española well field, and well fields for smaller communities such as Eldorado, south of Santa Fe (Figure 17). Table 16 lists the reported annual pumpages from these well fields and Figure 18 shows pumpages from the major well fields in the region.

The City of Santa Fe depends on both surface water and groundwater for its municipal water supply. The City diverts groundwater from both the Buckman well field and the City's well field centered on the western end of Santa Fe. The City began diverting water during 1950 from its local well field, the St. Michael's well was added to the supply system in 1961, and the Buckman well field was added in 1972. The average groundwater withdrawal from both well fields by the City of Santa Fe during the period 1950 to 1999 was 3,352 afy, and the average rate of pumping from 1990 through 1999 was 7,177 afy.

The Los Alamos well field began production in 1947, withdrawing 451 afy. This well field went out of service during 1993. The Guaje well field began production in 1950 and the Pajarito Mesa well field started operating in 1965; both are still active. The Otowi well field was added to the municipal supply system during 1993. Total pumping from all well fields in Los Alamos has varied from 451 afy in 1947 to 5,193 afy in 1976. The average total groundwater withdrawal for the period between 1947 and 1997 was 3,782 afy, and the average total pumpage for the period 1990 to 1997 was 4,418 afy. The City of Española well field began diverting groundwater in 1967. Annual pumping increased from 335 afy in 1967 to 1,336 afy in 1995. The average groundwater withdrawal rate for the period 1990 to 1997 was 1,170 afy.

Pumping from the Eldorado well field started in 1972 at a rate of 12 afy and increased to about 500 afy in 1999 (Shomaker and Associates, personal communication).



Source: Duke, 2001 (Figure 5-3)

JEMEZ Y SANGRE REGIONAL WATER PLAN

Municipal Well Field Locations

Figure 17

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Table 16. Annual Production of Major Well Fields
Page 1 of 2

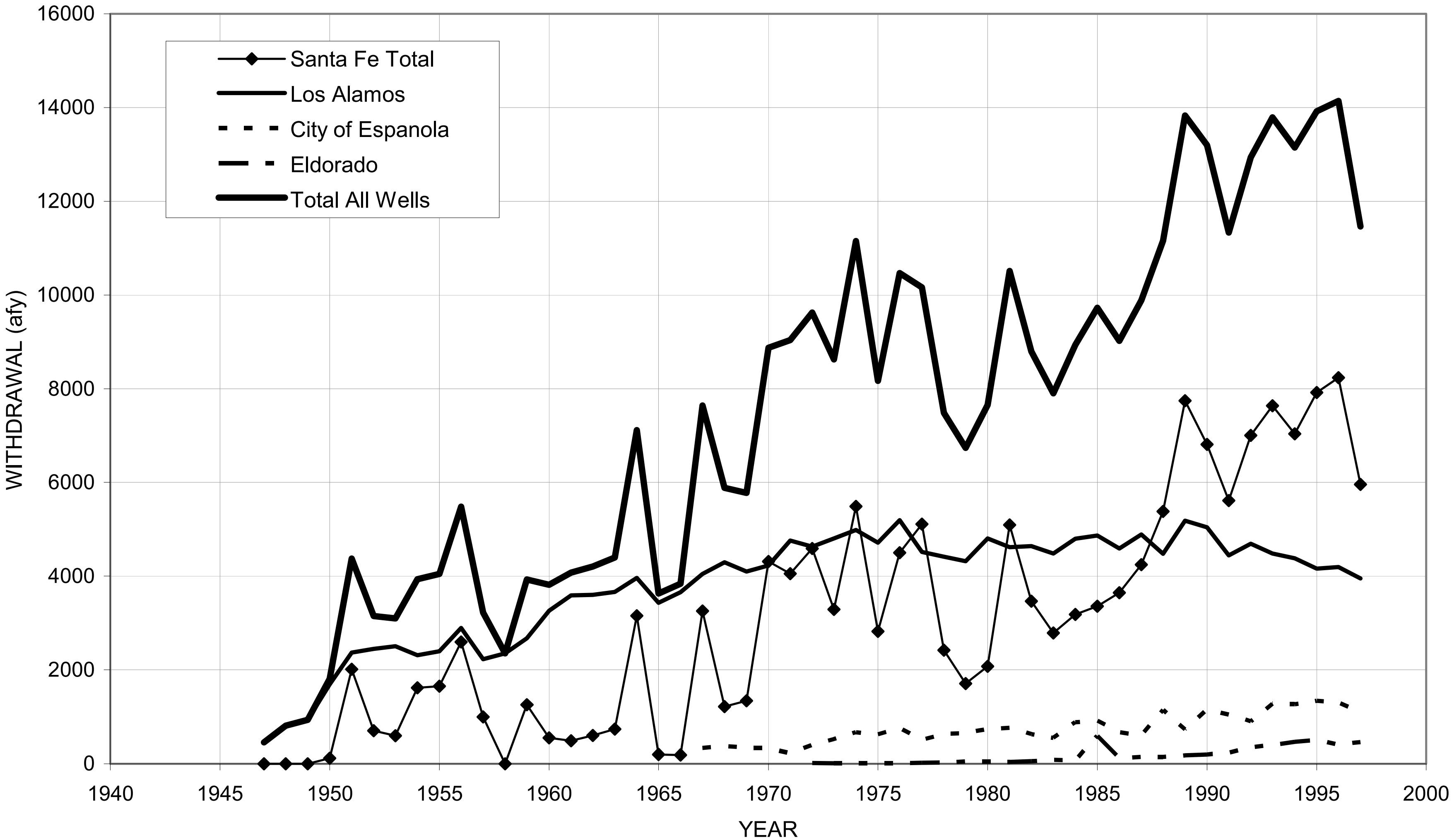
Year	Annual Production (acre-feet per year)					
	Santa Fe	Buckman	Los Alamos	Española	Eldorado	Total
1947	0	---	451	---	---	451
1948	0	---	810	---	---	810
1949	0	---	930	---	---	930
1950	121	---	1,688	---	---	1,809
1951	2,010	---	2,366	---	---	4,376
1952	699	---	2,449	---	---	3,148
1953	594	---	2,504	---	---	3,098
1954	1,618	---	2,314	---	---	3,932
1955	1,649	---	2,397	---	---	4,046
1956	2,594	---	2,891	---	---	5,485
1957	993	---	2,228	---	---	3,221
1958	0	---	2,354	---	---	2,354
1959	1,255	---	2,673	---	---	3,928
1960	550	---	3,262	---	---	3,812
1961	488	---	3,588	---	---	4,076
1962	601	---	3,603	---	---	4,204
1963	734	---	3,661	---	---	4,395
1964	3,154	---	3,962	---	---	7,116
1965	199	---	3,428	---	---	3,627
1966	185	---	3,655	---	---	3,840
1967	3,257	---	4,048	335	---	7,640
1968	1,213	---	4,297	374	---	5,884
1969	1,338	---	4,100	339	---	5,777
1970	4,315	---	4,229	328	---	8,872
1971	4,055	---	4,760	225	---	9,040
1972	3,739	849	4,628	393	15	9,625
1973	962	2,325	4,803	522	11	8,623
1974	2,202	3,288	4,984	664	11	11,149
1975	450	2,372	4,711	621	13	8,167
1976	1,801	2,700	5,193	758	14	10,465
1977	2,009	3,100	4,517	510	23	10,160
1978	810	1,609	4,413	627	26	7,485
1979	1,196	511	4,318	657	53	6,735
1980	1,565	507	4,803	733	46	7,654
1981	2,607	2,486	4,616	760	41	10,510

Source: Duke, 2001 (Table 5-1) --- = No data available

**Table 16. Annual Production of Major Well Fields
Page 2 of 2**

Year	Annual Production (acre-feet per year)					
	Santa Fe	Buckman	Los Alamos	Española	Eldorado	Total
1982	2,192	1,274	4,640	630	57	8,793
1983	2,772	16	4,484	547	82	7,901
1984	2,868	312	4,800	881	74	8,935
1985	2,227	1,130	4,864	914	590	9,726
1986	2,095	1,548	4,591	667	118	9,020
1987	2,800	1,442	4,889	603	150	9,884
1988	2,909	2,470	4,478	1,149	148	11,154
1989	3,192	4,551	5,180	727	181	13,831
1990	2,984	3,824	5,039	1,153	197	13,198
1991	2,427	3,186	4,444	1,045	230	11,332
1992	2,248	4,752	4,689	897	349	12,935
1993	2,027	5,610	4,484	1,275	395	13,791
1994	2,054	4,982	4,379	1,264	466	13,145
1995	2,026	5,891	4,161	1,337	503	13,918
1996	2,578	5,656	4,195	1,302	406	14,138
1997	1,241	4,716	3,950	1,094	460	11,461
1998	2,271	5,216	4,011	---	519	---
1999	2,802	5279	4,265	---	502	---
2000	3,828	5.080	4,862	---	533	---
2001	2,755	4,744	4,697	---	540	---
2002	3,702	5,837	---	---	---	---

Modified from Duke, 2001 (Table 5-1) --- = No data available



JEMEZ Y SANGRE REGIONAL WATER PLAN

Groundwater Withdrawals from Major Well Fields in the Planning Region

Figure 18

5.4 Water Quality

To characterize the water quality in the region, Duke (2001) focused on 19 measures of inorganic water quality including pH, total dissolved solids (TDS), dissolved aluminum, arsenic, barium, chloride, cyanide, fluoride, iron, lead, manganese, nickel, nitrate as nitrogen, silver, strontium, sulfate, tritium, and uranium. These measures were selected primarily because the New Mexico Environment Department (NMED) and/or the U.S. Environmental Protection Agency (EPA) have established either water quality standards or water quality guidelines for their occurrence. NMED criteria consist of drinking water standards published by the New Mexico Water Quality Control Commission (NMWQCC, 2000a). EPA's standards comprise maximum contaminant levels (MCLs), secondary drinking water regulations (SDWRs), and action levels (U.S. EPA, 2000). In addition to these indications, Duke also considered dissolved oxygen, nutrients, phosphorus, and hardness as described below.

An additional indicator of inorganic water chemistry is the degree of water oxygenation, which is also referred to as a dissolved oxygen (DO) percentage. DO percentage reflects the general health of a watercourse with regard to supporting aquatic organisms, such as those found in vital fisheries; the larger the DO percent, the more likely that a healthy fishery can be supported.

Nutrients in the form of ammonia and total phosphorous are also used as indicators of water quality. As measured by the USGS, total dissolved ammonia includes the ammonium ion (NH_4^+) and un-ionized ammonia (NH_3). Ammonia can be very toxic to fish at high levels, although it is usually a minor component at the pH levels commonly observed in streams and groundwater (USGS, 1999).

Elevated concentrations of dissolved phosphorous, can lead to nuisance plant growth (USGS, 1999). Phosphorous is also a major contributor to stream and lake eutrophication.

Water hardness is traditionally reported in terms of an equivalent concentration of calcium carbonate ($CaCO_3$). In practical water analysis, the hardness is computed by multiplying the sum of milliequivalents per liter of calcium and magnesium by 50 (Hem, 1989). The resulting equivalent concentration of calcium carbonate, expressed in units of milligrams per liter (mg/L) of $CaCO_3$, is categorized as follows with respect to hardness:

- 0 to 60 mg/L of $CaCO_3$ Soft
- 61 to 120 mg/L of $CaCO_3$ Moderately hard
- 121 to 180 mg/L of $CaCO_3$ Hard
- More than 180 mg/L of $CaCO_3$ Very hard

5.4.1 Surface Water Quality

Duke (2001) found that the general quality of surface waters in the Jemez y Sangre planning region is very good to excellent. The concentration of TDS in surface waters is typically less than 250 mg/L, substantially below the standards listed in Table 17 and well below the 1,000 to 3,000 mg/L range that the ISC uses to classify “slightly saline” waters (Duke, 2001). Surface waters throughout the planning region typically comply with the other standards and guidelines listed in Table 17, although there are scattered cases of high concentrations of inorganic ions dissolved in surface water, mostly in locales that are affected by some form of wastewater discharge.

The most abundant cation in regional surface waters is calcium, with sodium, magnesium, and iron occurring in lesser quantities. The predominant anions are bicarbonate and sulfate. Over most of the planning region, the surface water is characterized as calcium-bicarbonate, although calcium-magnesium-bicarbonate and sodium-bicarbonate types are occasionally observed (Duke, 2001). Most surface waters in the planning region are classified as moderately hard to hard because of their relatively high concentrations of calcium and magnesium.

Nutrients dissolved in surface waters occur in the planning region primarily as a result of agricultural land uses, although urbanization and wastewater discharges also contribute nutrients. The main stem Rio Grande receives dissolved nutrients from agricultural sources as far north as the San Luis Valley in southern Colorado and the Rio Chama above El Vado Reservoir. Noticeable nutrient source areas include irrigated areas near Española, one of the

Table 17. New Mexico Drinking Water Standards for Surface Water and EPA Drinking Water Standards

Constituent	New Mexico Surface Water Standard	EPA Drinking Water Standard
pH	6-9	6.5-8.5 [a]
Total Dissolved Solids (TDS)	---	500 mg/L [b]
Aluminum (Al)	---	0.05 mg/L [a]
Arsenic (As)	0.05 mg/L	0.05 mg/L [b], 0.005 mg/L [c]
Barium (Ba)	2.0 mg/L	2 mg/L [b]
Chloride (Cl)	---	250 [a]
Cyanide (CN)	0.2 mg/L	0.2 mg/L [b]
Fluoride (Fl)	---	2 [a]
Iron (Fe)	1.0 mg/L	0.3 mg/L [a]
Lead (Pb)	0.05 mg/L	0.015 mg/L [d]
Manganese (Mn)	---	0.05 [a]
Nickel (Ni)	0.1 mg/L	---
Nitrate as Nitrogen (NO_3 as N)	---	10 mg/L [b]
Selenium (Se)	0.05 mg/L	0.05 mg/L [b]
Silver (Ag)	---	0.1 [a]
Strontium (Sr)	8 pCi/L	---
Sulfate (SO_4)	---	250 mg/L [a]
Tritium (H_3)	20,000 pCi/L	---
Uranium (U)	5 mg/L	0.02 mg/L [c]

Source: Duke, 2001 (Table 4-1)

[a] EPA Secondary Drinking Water Regulation (SDWR) – a non-enforceable health goal which is set at a level at which no known or anticipated adverse effect on the health of persons occur and which allows an adequate margin of safety.

[b] EPA Maximum Contaminant Level (MCL) – the highest level of a contaminant that is allowed in drinking water. MCLs are enforceable.

[c] Proposed MCL.

[d] EPA Action Level (AL) – the concentration of a contaminant which, if exceeded, triggers treatment or other requirements which a water system must follow. For lead it is the level which, if exceeded in over 10% of the homes tested, triggers treatment.

EPA = U.S. Environmental Protection Agency
--- = Not applicable
mg/L = Milligrams per liter
pCi/L = Picocuries per liter

more urbanized locales in the planning region, and the lower Santa Fe River downstream of the City of Santa Fe. Surface water in the Pojoaque Valley also occasionally contains elevated levels of nutrients, including ammonia.

A TMDL is a watershed or basin-wide budget for pollutant influx to a watercourse. A TMDL can also be established for a portion or a segment of a watershed. The NMWQCC is responsible for setting TMDLs in New Mexico. TMDLs are set for one or more constituents that have historically exceeded water quality standards. Since this program began, a variety of stream reaches within the planning region have been the subject of TMDL assessments. Table 18 lists the stream reaches within the planning region that are currently undergoing assessment, and provides a brief summary of the pollutants examined for each reach and the current TMDL status. Contaminants of concern being addressed by the TMDL program include turbidity, stream bottom deposits, pesticides, chlorine, pH, DO, and fecal coliform.

As Table 18 indicates, the Santa Fe River is the only watercourse in the planning region for which the NMWQCC has set TMDL-based limits. Specifically, for the reach of the river lying between the Santa Fe wastewater treatment plant (WWTP) and Cochiti Reservoir, loading limits have been established for chlorine and stream bottom deposits. Both DO and pH have been assessed on this reach, but have not been assigned TMDL-based limits. Also, although nitrate levels downstream of the WWTP were observed to be as high as 5.0 mg/L during the National Water Quality Assessment Program, no TMDL-based limits have been established for nitrate.

The TMDL study of the Santa Fe River identified a distinct link between chlorine in the river and effluent from the Santa Fe WWTP. A study by CDM (1998) provided evidence that the source of virtually all total residual chlorine in the river was the WWTP and that levels of this dissolved constituent decrease downstream of the WWTP. The Santa Fe WWTP has replaced its chlorination system with an ultraviolet disinfection system which will help it meet TMDL-based limits for chlorine.

Table 18. Total Maximum Daily Load Status of Streams in the Jemez y Sangre Water Planning Region
Page 1 of 4

Water Body Name, (Basin, Segment) Evaluated or Monitored Support Status, WBS Number	Affected Reach (miles)	Probable Sources of Pollutant	TMDL Due Date	NPDES Permits on the Reach	Uses not fully Supported	Specific Pollutant	Acute Public Health Concern
Pojoaque River from mouth on Rio Grande to Nambe Dam (Rio Grande, 2111), Evaluated Partially Supported, (URG1-10200)	14.4	Rangeland, removal of riparian vegetation, streambank modification/ destabilization	12/31/2017	• Pojoaque Terraces Mobile Home Park (NM0028436) • Pojoaque Valley Schools-Jacona Site (NM0029882)	MCWF, WWF	Stream bottom deposits	No
Tesuque Creek from the confluence with Little Tesuque Creek to the confluence of North and South Forks of Tesuque Creek (Rio Grande, 2118), Monitored Not supported, (URG0-10230)	6.7	Removal of riparian vegetation, streambank modification/ destabilization	12/31/2017	None	HQCWF	Turbidity	No
Little Tesuque Creek from Big Tesuque Creek to headwaters (Rio Grande, 2118), Monitored Not supported, (URG1 – 10230)	8.1	Recreation	12/31/2017	None	HQCWF	Turbidity	No
Little Tesuque Creek from Big Tesuque Creek to headwaters (Rio Grande, 2118), Monitored Not Supported., URG1 – 10230)	8.1	Natural, unknown	12/31/2017	None	HQCWF	Metals	No

Source: Duke, 2001 (Table 4-2); NMED web site, 2002
TMDL = Total maximum daily load
WBS = Water body segment
NPDES =National Pollutant Discharge Elimination System
WWTP =Wastewater treatment plant

HQCWF = High quality coldwater fishery
MCWF = Marginal coldwater fishery
WWF = Warmwater fishery
LW = Livestock watering

Table 18. Total Maximum Daily Load Status of Streams in the Jemez y Sangre Water Planning Region
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Water Body Name, (Basin, Segment) Evaluated or Monitored Support Status, WBS Number	Affected Reach (miles)	Probable Sources of Pollutant	TMDL Due Date	NPDES Permits on the Reach	Uses not fully Supported	Specific Pollutant	Acute Public Health Concern
Rio Frijoles from confluence with Rio Medio to Pecos Wilderness boundary (Rio Grande, 2112), Evaluated Partially Supported, (URG1 – 10240)	2.5	Unknown	12/31/2017	None	HQCWF	Unknown	No
Rio Chupadero from USFS boundary to headwaters (Rio Grande, 2118), Monitored Not Supported, (URG1 – 10240)	4.1	Road maintenance/ runoff, recreation, unknown	12/31/2017	None	HQCWF	Turbidity	No
Rio Chupadero from USFS boundary to headwaters (Rio Grande, 2118), Monitored Not Supported, (URG1 – 10240)	4.1	Road maintenance/ runoff, recreation, unknown	12/31/2017	None	HQCWF	Turbidity	No
Rito Canon de Frijoles from mouth on the Rio Grande headwaters (Rio Grande, 2118), Monitored Partially Supported, (MRG1 – 20100)	2.8	Land disposal	12/31/2017	None	HQCWF	Pesticide (DDT)	No
Santa Fe River from the Cochiti Pueblo to the Santa Fe WWTP (Rio Grande, 2110), Monitored Not Supported, (URG1 – 10300)	12.7	Municipal point sources	12/31/1999	Santa Fe WWTP (NM0022292)	MCWF, WWF, LW	Dissolved oxygen	No

Source: Duke, 2001 (Table 4-2); NMED web site, 2002
TMDL = Total maximum daily load
WBS = Water body segment
NPDES =National Pollutant Discharge Elimination System
WWTP =Wastewater treatment plant

HQCWF = High quality coldwater fishery
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Table 18. Total Maximum Daily Load Status of Streams in the Jemez y Sangre Water Planning Region
Page 3 of 4

Water Body Name, (Basin, Segment) Evaluated or Monitored Support Status, WBS Number	Affected Reach (miles)	Probable Sources of Pollutant	TMDL Due Date	NPDES Permits on the Reach	Uses not fully Supported	Specific Pollutant	Acute Public Health Concern
Santa Fe River from the Cochiti Pueblo to the Santa Fe WWTP(Rio Grange, 2110), Monitored Not Supported, (URG1 – 10300)	12.7	Municipal point sources, rangeland, resource extraction	TMDL witten and WQCC approved	Santa Fe WWTP (NM0022292)	MCWF, WWF, LW	Chlorine	No
Santa Fe River from the Cochiti Pueblo to the Santa Fe WWTP (Rio Grande, 2110), Monitored (URG1 – 10300)	12.7	Municipal point sources, rangeland, resource extraction	TMDL written and WQCC approved	Santa Fe WWTP (NM0022292)	MCWF, WWF, LW	Stream bottom deposits	No
Santa Fe River from the Cochiti Pueblo to the Santa Fe WWTP (Rio Grande, 2110), Monitored Not Supported, (URG1 – 10300)	12.7	Municipal point sources, rangeland, resource extraction	12/31/1999	Santa Fe WWTP (NM0022292)	MCWF, WWF, LW	pH	No
Cienega Creek from the mouth on the Santa Fe to Cienega Village (Rio Grande, 2110), Monitored Partially Supported, (URG1 – 10310)	4.1	Rangeland, land disposal,unknown	12/31/2017	• Valle Vista Sewer Company (NM0028614) • Arroyo Hondo (Geohydrology Association) (NM0029823)	MCWF, WWF, IRR	Fecal coliform	No

Source: Duke, 2001 (Table 4-2); NMED web site, 2002
TMDL = Total maximum daily load
WBS = Water body segment
NPDES =National Pollutant Discharge Elimination System
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HQCWF = High quality coldwater fishery
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Table 18. Total Maximum Daily Load Status of Streams in the Jemez y Sangre Water Planning Region
Page 4 of 4

Water Body Name, (Basin, Segment) Evaluated or Monitored Support Status, WBS Number	Affected Reach (miles)	Probable Sources of Pollutant	TMDL Due Date	NPDES Permits on the Reach	Uses not fully Supported	Specific Pollutant	Acute Public Health Concern
Cienega Creek from the mouth on the Santa Fe to Cienega Village (Rio Grande, 2110), Monitored Partially Supported, (URG1 – 10310)	4.1	Rangeland, land disposal	12/31/2017	• Valle Vista Sewer Company (NM0028614) • Arroyo Hondo (Geohydrology Association) (NM0029823)	MCWF, WWF, IRR	Chlorine	No
Galisteo Creek, perennial portions (Rio Grande, unclassified), Evaluated Partially Supported	5.5	Rangeland, hydromodification, removal of riparian vegetation, streambank modification/ destabilization	12/31/2017	None	WWF	Stream bottom deposits	No

Source: Duke, 2001 (Table 4-2); NMED web site, 2002
TMDL = Total maximum daily load
WBS = Water body segment
NPDES =National Pollutant Discharge Elimination System
WWTP =Wastewater treatment plant

HQCWF = High quality coldwater fishery
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WWF = Warmwater fishery
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The Santa Fe WWTP is not the only source for suspended solids on the Santa Fe River, but it is the only known point source. Currently, the plant is permitted to have effluent discharge containing 30 mg/L total suspended solids (TSS). The geometric mean of TSS measurements in WWTP effluent from data collected between July 1998 and June 1999 was 1.0 mg/L (Duke, 2001). From January 1995 to December 1995, the geometric mean load was 6.3 mg/L. For TMDL purposes, the waste load allocation for TSS in Santa Fe WWTP effluent is based on the WWTP's current permitted TSS concentration of 30 mg/L and the plant's design flow of 8.5 million gallons per day (mgd). Thus, on the basis of TSS information collected during the 1990s, it appears that the WWTP is meeting its allocation criteria.

Other potential point sources of surface water pollution in the planning region were identified through inspection of a list of permitted National Pollutant Discharge Elimination System (NPDES) sites. Duke (2001) lists the NPDES sites within the planning region.

The NMED has expressed concern that non-point sources of pollution in New Mexico may constitute one of the more serious water quality problems facing the state (NMWQCC, 2000b). Non-point pollution is diffuse in origin, the result of rain or snowmelt carrying pollutants from the land into streams, lake, and rivers. The principal contaminants contributed from this type of pollutant source are nutrients, sediments, toxic substances, organic matter, salts, metals, and petroleum and its byproducts. The NMED estimates that about 92 percent of known river water quality impairment in the state is due to non-point sources (NMWQCC, 2000b). The occurrence of significant agriculture activity and urbanization within the Jemez y Sangre planning region makes it likely that some surface water quality degradation is attributed to this type of source.

To study potential surface water contamination resulting from its operations, LANL conducted a study of plutonium and uranium in the sediments of the Northern Rio Grande Valley (Gallaher and Efurd, 2002). Samples of stream channel and reservoir bottom sediments were analyzed for plutonium and uranium isotopes. Isotopic fingerprinting techniques were used to help distinguish radioactivity from LANL from global fallout or natural sources. Of the seven major drainages crossing LANL, movement of LANL plutonium into the Rio Grande was traced only via Los Alamos Canyon. The LANL plutonium is identifiable intermittently along the 35-

kilometer reach of the Rio Grande to Cochiti Reservoir and can be traced primarily to pre-1960 discharges of liquid effluents upstream of the river. Levels of plutonium in the Rio Grande are usually more than 1,000 times lower than EPA cleanup levels (Gallaher and Efurd, 2002). None of the sediments from the Rio Grande showed identifiable LANL uranium, though historical monitoring records show a slight LANL impact.

5.4.2 Groundwater Quality

Groundwater in the planning region is generally of high quality. Except for several isolated locations where either natural or human processes have led to elevated levels of specific dissolved constituents, groundwater is suitable for domestic consumption. Table 19 lists the drinking water standards set by both the State of New Mexico and the EPA. The state criteria consist of drinking water standards published by the NMED Ground Water Quality Bureau. As with surface water standards, EPA's standards comprise MCLs, SDWRs, and action levels (U.S. EPA, 2000).

5.4.2.1 Nitrate

Nitrate is observed at relatively high concentrations at several locales in the planning region; Figure 19 illustrates locations where nitrate concentrations exceed the drinking water standard. Though this constituent occurs naturally within regional groundwater, nitrate background levels are generally very low in comparison to the drinking water standard of 10 mg/L as nitrogen (Table 19). Thus, elevated levels of nitrate are usually attributed to sources for such as fertilizer application, septic tank discharge, or surface water bodies that receive some form of effluent. Fluoride is another naturally occurring inorganic solute that sometimes occurs at elevated or problematic concentrations in groundwater.

5.4.2.2 Electrical Conductivity and Total Dissolved Solids

As part of an assessment of general groundwater quality in Santa Fe County, DBS&A (1994) developed mathematical relationships between measured TDS levels and corresponding measures of electrical conductivity (EC). In most cases, the resulting equations suggest that multiplying EC by a factor of about 0.6 to 0.7 will produce a viable estimate of TDS. Using this

Table 19. New Mexico Drinking Water Standards for Groundwater and EPA Drinking Water Standards

Constituent	New Mexico Surface Water Standard	EPA Drinking Water Standard
pH	6-9	6.5-8.5 [a]
Total Dissolved Solids (TDS)	1,000 mg/L	500 mg/L [b]
Aluminum (Al)	5 mg/L	0.05-0.2 mg/L [a]
Arsenic (As)	0.1 mg/L	0.05 mg/L [b], 0.005 mg/L [c]
Barium (Ba)	1.0 mg/L	2 mg/L [b]
Boron (B)	0.75 mg/L	---
Chloride (Cal)	250 mg/L	250 mg/L [a]
Cyanide (CN)	0.2 mg/L	0.2 mg/L [b]
Fluoride (Fl)	1.6 mg/L	2 mg/L [a]
Iron (Fe)	1.0 mg/L	0.3 mg/L [a]
Lead (Pb)	0.05 mg/L	0.015 mg/L [d]
Manganese (Mn)	0.2 mg/L	0.05 mg/L [a]
Nickel (Ni)	0.2 mg/L	---
Nitrate as Nitrogen (NO_3 as N)	10 mg/L	10 mg/L [b]
Selenium (Se)	0.05 mg/L	0.05 mg/L [b]
Silver (Ag)	0.05 mg/L	0.1 mg/L [b]
Strontium (Sr)	8 pCi/L	---
Sulfate (SO_4)	600 mg/L	250 mg/L [a]
Tritium (H_3)	20,000 pCi/L	---
Uranium (U)	5 mg/L	0.02 mg/L [c]

Source: Duke, 2001 (Table 6-1).

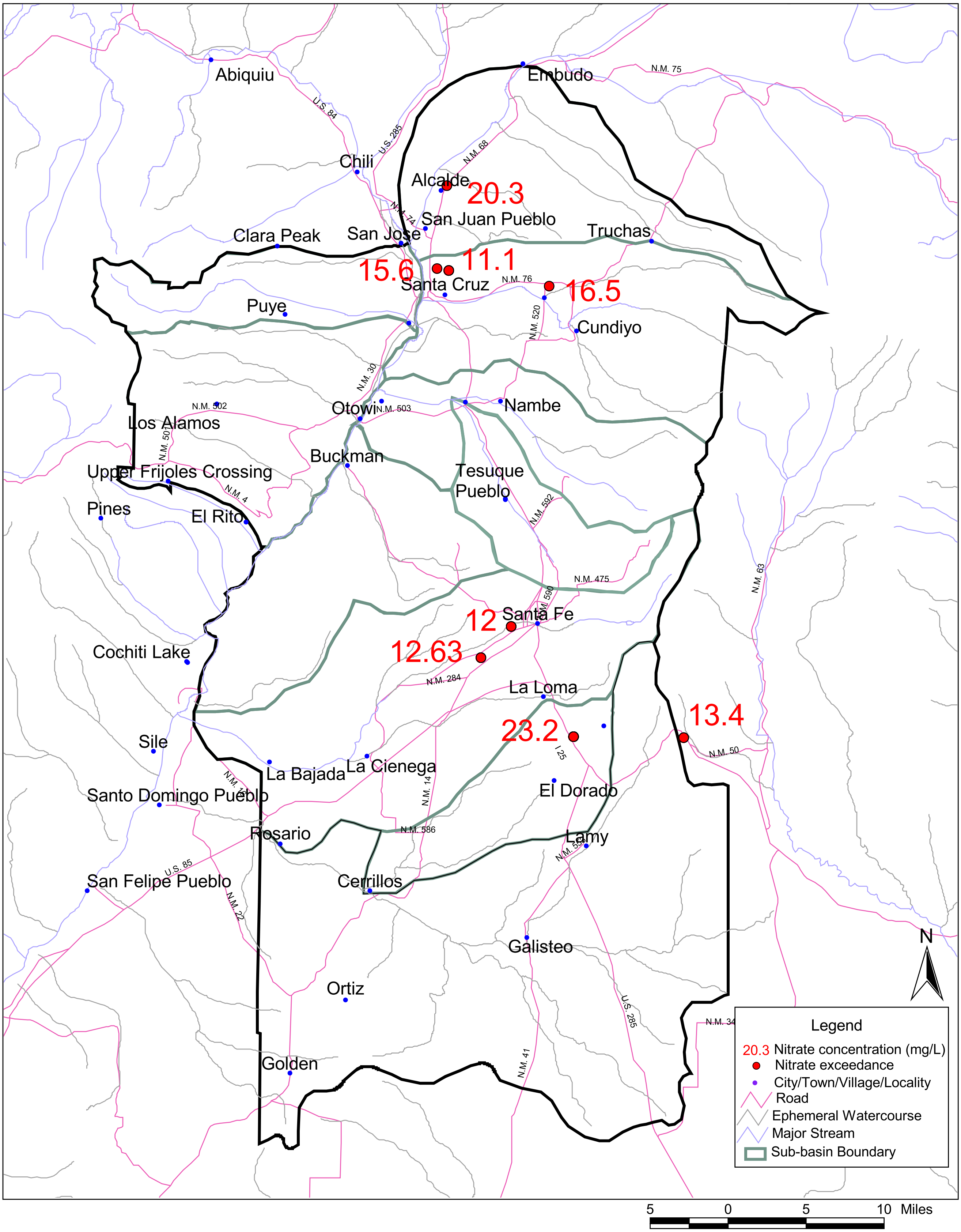
[a] EPA Secondary Drinking Water Regulation (SDWR) – a non-enforceable health goal which is set at a level at which no known or anticipated adverse effect on the health of persons occur and which allows an adequate margin of safety.

[b] EPA Maximum Contaminant Level (MCL) – the highest level of a contaminant that is allowed in drinking water. MCLs are enforceable.

[c] Proposed MCL.

[d] EPA Action Level (AL) – the concentration of a contaminant which, if exceeded, triggers treatment or other requirements which a water system must follow. For lead it is the level which, if exceeded in over 10% of the homes tested, triggers treatment.

EPA = U.S. Environmental Protection Agency
mg/L = Milligrams per liter
pCi/L = Picocuries per liter
--- = Not applicable



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JEMEZ Y SANGRE REGIONAL WATER PLAN

Nitrate Exceedances

Figure 19

general rule, measurements of EC can be used to describe the spatial distribution of dissolved solids levels within the Santa Fe County portion of the planning region.

North of the town of Galisteo, particularly in areas where wells tap either the Tesuque Formation, the Ancha Formation, Precambrian rocks, or shallow alluvium adjacent to watercourses, EC levels in groundwater on the eastern side of the Rio Grande usually range from about 100 to 500 micromhos per centimeter (µmhos/cm). Thus, the TDS levels over most of this part of the planning region can be expected to be 350 mg/L or less. Isolated wells showing EC measurements in excess of 700 µmhos/cm are observed near the City of Santa Fe, in a shallow aquifer near Española, in the Buckman well field, near the community of Pojoaque, and just south of the southernmost extent of Santa Fe Group deposits within the planning region.

Most EC levels in the South Galisteo Creek Sub-Basin indicate that TDS levels in this southernmost portion of the planning region will exceed the New Mexico groundwater standard of 1,000 mg/L. Near the town of Galisteo, measured EC levels range from about 650 to 2,200 µmhos/cm. In this same sub-basin near the west boundary of the planning region, EC measurements generally range from 1,000 to 5,000 µmhos/cm.

Within the Los Alamos Sub-Basin west of the Rio Grande, measured TDS levels are generally less than 350 mg/L. Water supply wells that tap the so-called regional aquifer in the Pajarito Mesa, Guaje Canyon, and Otowi well fields typically yield groundwater with TDS concentrations of 150 to 500 mg/L. TDS concentrations exceeding 600 mg/L have been observed in some of the wells in the Los Alamos well field (Duke, 2001).

The Los Alamos well field, formerly used for water supply to the community of Los Alamos, is now owned by the San Ildefonso Pueblo. An area of relatively high TDS concentration, with values sometimes exceeding 1,000 mg/L, has been observed in wells near the Rio Grande between the historic townsites of Otowi and Pajarito, just north of where Guaje Canyon empties into the Rio Grande Valley. These relatively high concentrations of dissolved solids occur on the western side of San Ildefonso Pueblo, in conjunction with anomalous concentrations of nitrate and sulfate.

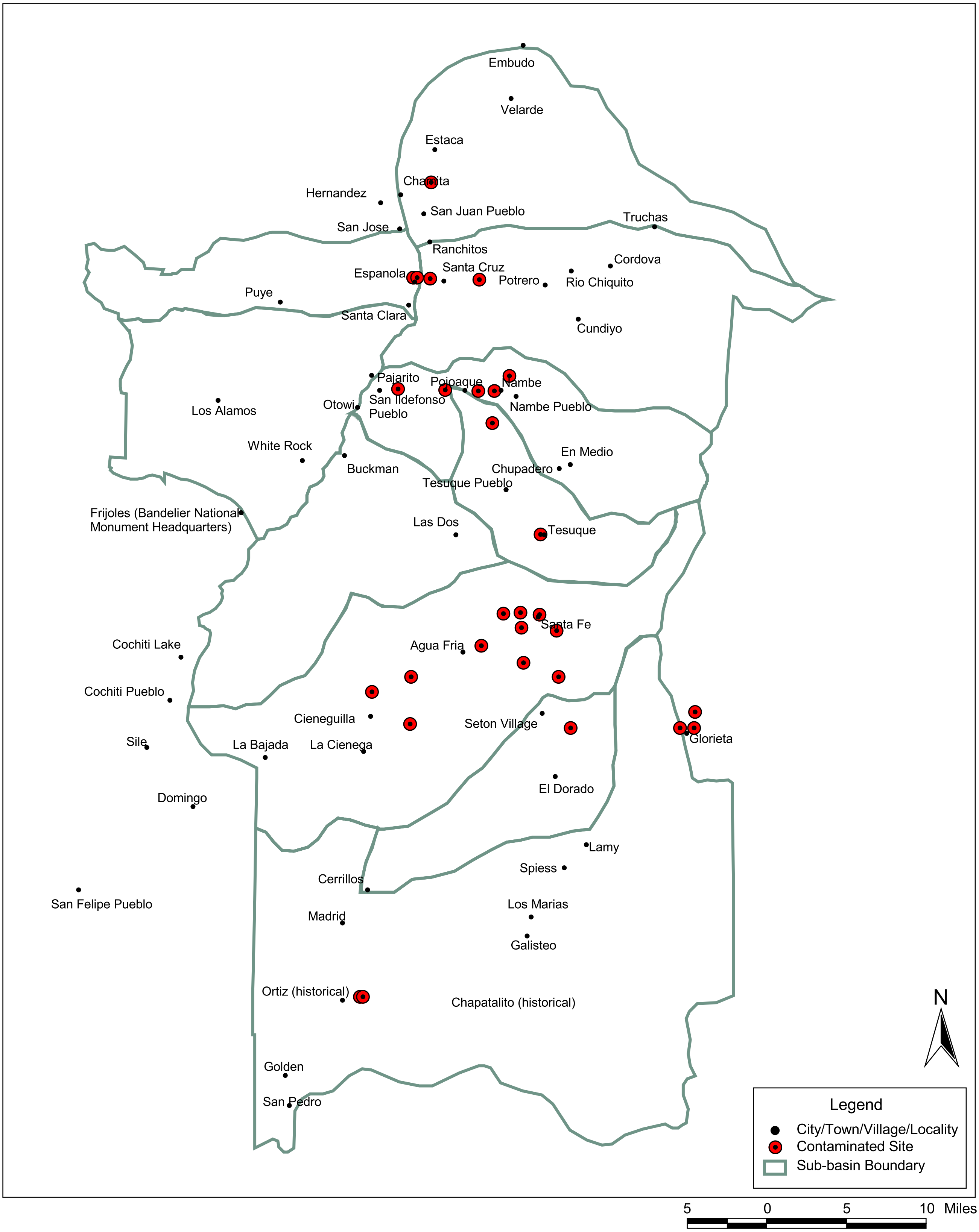
5.4.2.3 Known Groundwater Contamination

Duke catalogued known groundwater contamination sites, showing observed contaminants ranging from gasoline components to chlorinated solvents, pesticides, and radionuclides. Sources associated with the contaminants including leaking underground storage tanks, LANL, dry cleaning facilities, sewage treatment plants, and railroad and mining operations. Contamination has temporarily affected the use of some Española and City of Santa Fe supply wells and some domestic wells. Additionally, the presence of contaminated groundwater limits the suitability of some locations for future development.

Figure 20 shows the locations of known contamination sites, most of which occur near urbanized areas, such as the City of Santa Fe, Española, and the Pueblo of Pojoaque.

Two inorganic constituents that occur naturally in groundwater will likely be of concern to the Jemez y Sangre planning region because of changes to drinking water standards that will soon be enforced by the EPA. One of these constituents is arsenic, which currently is subject to an MCL of 0.05 mg/L. In January 2006, however, this MCL will be reduced to 10 micrograms per liter (µg/L) (0.010 mg/L), a level that is commonly exceeded in regional groundwater under natural conditions. The second constituent is uranium, for which the New Mexico drinking water standard is 5 mg/L. The EPA does not currently have a mass concentration standard for uranium in groundwater, but a new uranium MCL of 30 µg/L (0.03 mg/L) will take effect on December 8, 2003.

Most groundwater within the planning region meets the current arsenic MCL of 0.05 mg/L. All of the New Mexico Drinking Water Bureau (NMDWB) analyses for community water supply systems in the planning region, as taken from the Tier 1 database, show arsenic occurring at concentrations less than this value. However, out of 290 NMDWB samples included in the database, 22 have arsenic levels that are equal to or exceed the new MCL of 10 µg/L (0.01 mg/L). Thus it appears that some community systems may have to provide treatment for



Source: Duke, 2001 (Figure 6-9)

JEMEZ Y SANGRE REGIONAL WATER PLAN

Known Groundwater Contamination Sites in the Planning Region

Figure 20

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5.4.3 Summary of Water Quality by Sub-Basin

The following discussion summarizes the overall water quality for each of the ten sub-basins in the Jemez y Sangre planning region, beginning with Velarde Sub-Basin in the northern part of the region and moving generally southward (Figure 1). Information about general sub-basin characteristics is provided in Section 3, while Section 6 provides sub-basin water budgets (inflow and outflow). More detailed sub-basin characterizations can be found in Duke (2001).

- *Velarde Sub-Basin*: In general, water supplies meet applicable water quality standards, with the exception of the new arsenic standard. However, water quality concerns exist due to septic tank discharges. For example, there is an area of high nitrate in excess of drinking water standards in Alcalde.

- *Santa Clara Sub-Basin*: Water quality information for Santa Clara Creek is limited; however, it is likely similar to Rito de los Frijoles in Bandelier National Monument to the south. Both Rito de los Frijoles and Santa Clara Creek drain Tertiary volcanic tuff on the eastern flank of the Jemez Mountains, and both are subject to some recreational and cattle grazing land use. The Cerro Grande fire (May 2000) burned through the headwater area of Santa Clara Creek, affecting runoff and water quality.

- *Santa Cruz Sub-Basin*: Surface water quality is generally good; only iron and manganese were noted as having somewhat elevated concentrations when sampling was done in the late 1980s. The groundwater quality is generally very good except in the more congested areas, where septic tanks and drain fields have locally raised nitrate levels. Additionally, naturally occurring arsenic exceeds the new MCL in this sub-basin.

- *Los Alamos Sub-Basin*: The Los Alamos County public water supply meets drinking water quality standards, with the exception of the new arsenic standard. In addition to the public water supply, there are a few individual domestic water supply wells. Residual contamination associated with historical operations of LANL is a concern, and LANL is taking corrective action under its Environmental Restoration Project to address these concerns. LANL has an ongoing surveillance and monitoring program to assess the quality of surface water and groundwater. In addition, the public water supply is monitored to ensure it meets applicable water quality standards.

- *Pojoaque-Nambe Sub-Basin*: In general the quality of the groundwater is good, although local water quality problems include naturally occurring high levels of fluoride, uranium, and arsenic. Also, as in many other sub-basins, areas with higher population density have higher levels of nitrate associated with the use of septic tanks.

- *Tesuque Sub-Basin*: Surface water quality is very good overall with occasional elevated concentrations of iron, lead, and aluminum. The new arsenic standard is also exceeded in some locations. The source of these elevated concentrations is unknown, but might be natural weathering of the granitic core rock in the Sangre de Cristo Range, runoff (from roads, building sites, or the Santa Fe Ski area), or some combination of these. Groundwater is also of high quality in most of the Tesuque Sub-Basin with only a few localized areas having elevated nitrate levels due to agricultural fertilizers or concentrated septic leach fields. Except in local areas where nitrate levels are high, the calcium-bicarbonate groundwater meets drinking water standards and contains relatively low levels of total dissolved solids.

- *Caja del Rio Sub-Basin*: Assessment of water quality indicates localized impacts to surface waters associated with cattle use. Additionally, some wells in the Buckman well field experience elevated levels of natural radionuclides of concern and the new arsenic standard is exceeded in some locations.

- *Santa Fe River Sub-Basin*: The water quality is naturally very good, but the water is hard due to the concentrations of calcium and magnesium. The TDS concentration is generally less than 350 mg/L. Nitrate from an unknown source has been detected in many of the City wells at concentrations slightly above the 10 mg/L standard and the new arsenic standard is exceeded in some locations. Downstream of the City's wastewater treatment plant, nitrate concentration in the groundwater range from 4 to 6 mg/L. Within the City limits, leaking underground storage tanks have contaminated the groundwater in several locations. Chlorinated solvents have contaminated one City well and tetracholoroethene (PCE) from a dry cleaning operation has been detected beneath the railyard property. The railyard site is being developed as a Brownfields Superfund Site.

- *North Galisteo Creek Sub-Basin*: Water quality is generally very good, but the water is hard due to concentrations of naturally occurring calcium and magnesium. Given the few potential sources for contamination in this sub-basin, very few groundwater contamination problems exist. Nitrate occurs in wells along the mountain front in concentrations commonly ranging from 3 to 5 mg/L (as nitrogen). Pesticides have been detected in Cañoncito wells.

- *South Galisteo Sub-Basin*: Water quality is naturally quite variable. TDS can reach as high as 3,500 mg/L, much higher than the New Mexico drinking water standard of 1,000 mg/L. The cyanide heap leach operation in the Ortiz Mountains resulted in cyanide and metals contamination in groundwater and surface water near the mine. The pesticide Atrazine has been detected in wells in Lamy, the Girls Ranch, and Glorieta. A leaking underground storage tank has resulted in gasoline contamination of groundwater near Galisteo.

5.5 Summary of Water Supply Considering Legal Limitations

Water supplies in the Jemez y Sangre planning region are (or have the potential to be) affected by a number of legal limitations. Surface waters below the Velarde Sub-Basin and Otowi Gage are fully appropriated and are subject to Rio Grande Compact deliveries. As mentioned in Appendix D, the Rio Grande Compact specifies that New Mexico must make deliveries to Elephant Butte Reservoir based on an inflow-outflow gaging schedule premised on uses as of 1929. A junior water right that violates the Rio Grande Compact cannot be used. For example, if there is less than 400,000 acre-feet of usable water in Elephant Butte and Caballo Reservoirs, storage of water may not be increased in upstream reservoirs with post-1929 storage rights, such as Nichols and McClure Reservoirs near Santa Fe, unless other water sources are substituted. This limitation pertains only to post-1929 storage rights, but these comprise approximately 75 percent of the rights in these two reservoirs. Also, if New Mexico is in debit status under the Rio Grande Compact, Texas may demand releases from post-1929 reservoirs until Elephant Butte project storage is brought up to its regular annualized amount of 790,000 acre-feet. As mentioned in Section 4, however, SJC Project water is exempt from obligation under the Rio Grande Compact.

Pueblo water rights are exempted from the Rio Grande Compact. Because Pueblo water rights are the most senior rights in the planning region, they have the potential to limit more junior rights (Section 4.3). Existing uses and rights may also be affected by ongoing adjudications for the Rio Pojoaque system, Rio Santa Cruz and Rio de Truchas system, Rio Chama system, and Santa Fe River system (Section 4.2.5). Water supply and use may also be limited by ESA-mandated protection of two threatened and endangered species, the Rio Grande silvery minnow and the Southwestern willow flycatcher.

Local governments (cities and counties) have the authority to enforce ordinances to conserve and regulate the use of water within their jurisdictions, which may include restrictions on the issuance of domestic well permits (Section 4.6). Municipalities and counties may also exercise powers of eminent domain to establish or expand water utilities and, as part of this process, condemn existing water supplies, rights, or rights-of-way.